



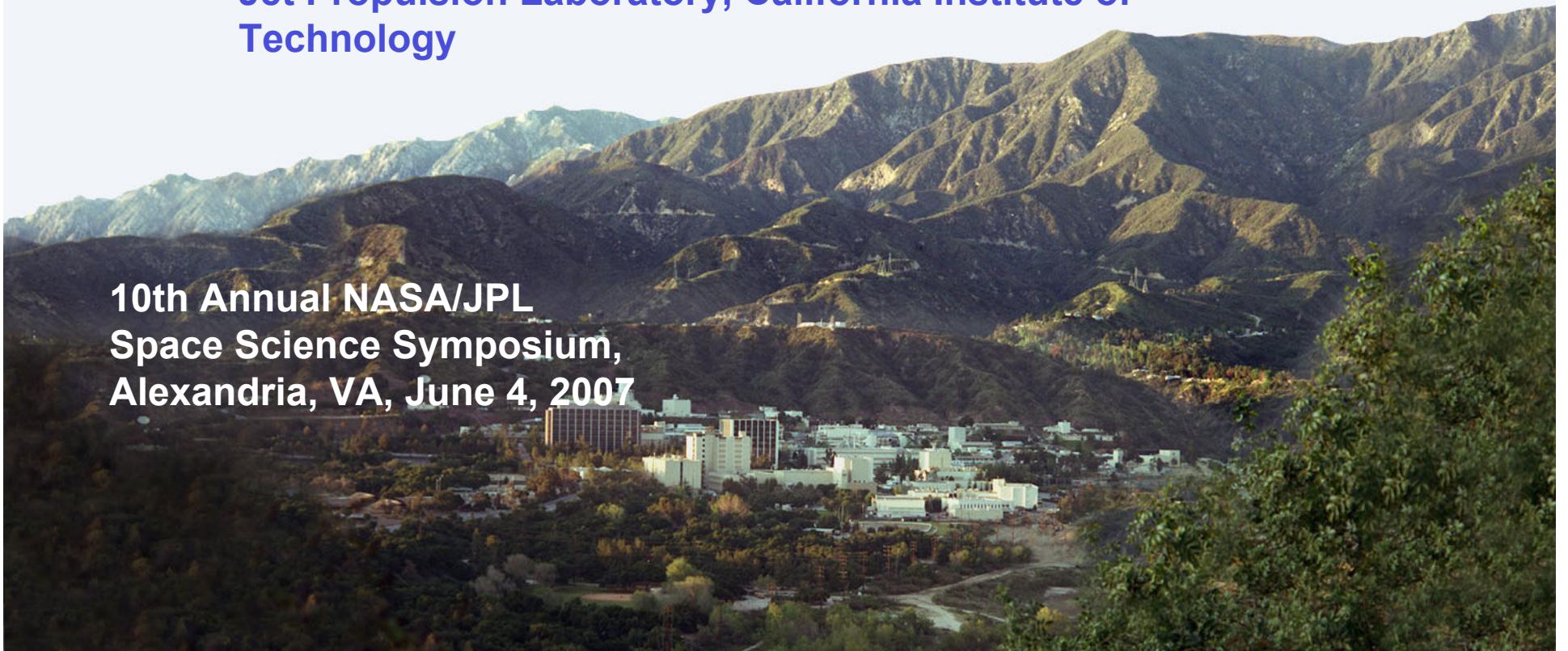
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Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

JPL's Science Missions: New Places, New Worlds

Jason Hyon, Chief Technologist, ESTD
Jet Propulsion Laboratory, California Institute of
Technology

**10th Annual NASA/JPL
Space Science Symposium,
Alexandria, VA, June 4, 2007**





The NASA Vision

To improve life here,
To extend life to there,
To find life beyond.

The NASA Mission

To understand and protect our home planet,
To explore the universe and search for life,
To inspire the next generation of explorers
... as only NASA can.



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JPL's Science Missions: New Places, New Worlds

- **Highlight New Places or Worlds Visited Recently**
- **Earth Science Technology Needs**
- **Missions now under development**



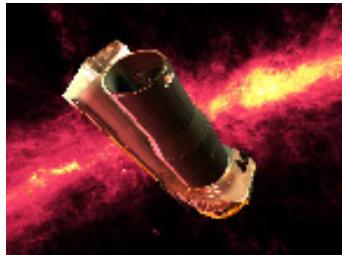
The Rover that didn't get to go to Mars



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Fourteen JPL spacecraft - and three major instruments- now operating across the solar system



Spitzer studying stars and galaxies in the infrared



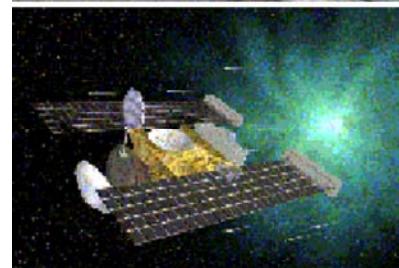
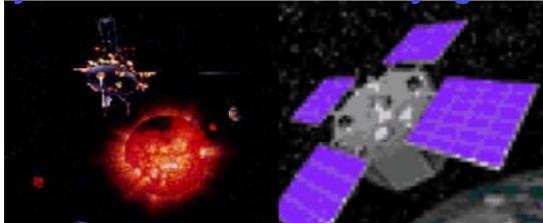
Two Voyagers on an interstellar mission

Cassini studying Saturn and its moons



GALEX studying UV universe

Ulysses and ACRIMSAT studying the Sun



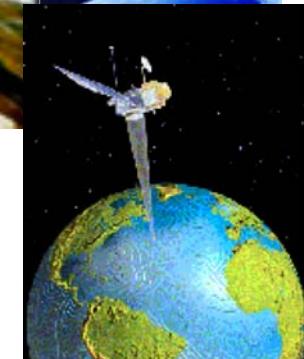
Stardust returning comet dust



Mars reconnaissance Orbiter and Mars Odyssey; "Spirit" and "Opportunity" on Mars



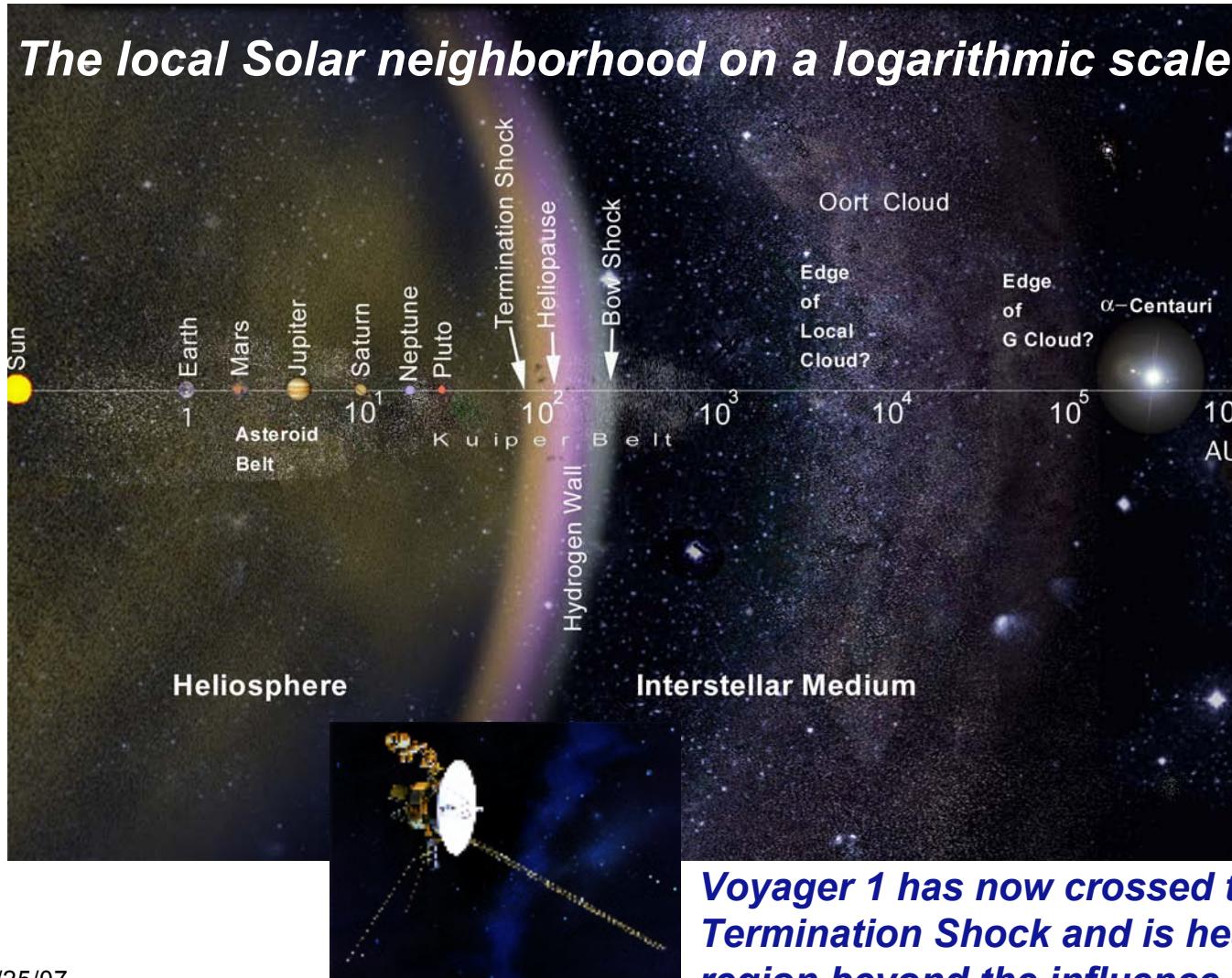
QuikSCAT, Jason 1, and GRACE (plus ASTER, MISR, and AIRS, MLS, TES) monitoring Earth





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Voyager 1, now 28 years after launch: Reaches the Edge of the Solar System



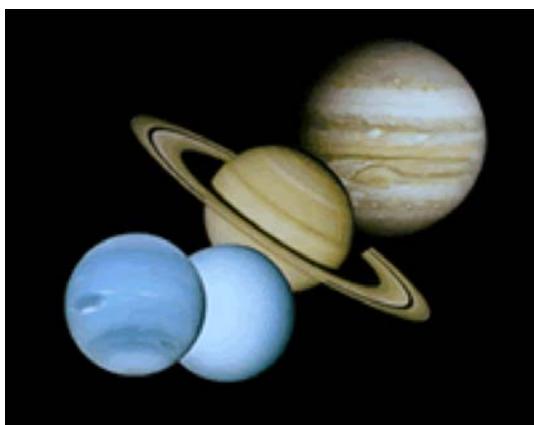


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Voyager Spacecraft Enters Solar System's Final Frontier

- *NASA's Voyager 1 spacecraft has entered the solar system's final frontier. It is entering a vast, turbulent expanse where the Sun's influence ends and the solar wind crashes into the thin gas between stars.*
- The Voyagers may reach the *interstellar medium* before losing power in about 2020. Interstellar medium is gas from other stars.



The Voyagers hold the record for the most new worlds visited: All the gas giants (left to right) Neptune, Uranus, Saturn, Jupiter (1977-1989)



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Deep Impact Mission

Spacecraft carries the Impactor to the comet,
then flies on by to observes the results

Launched in January 2005



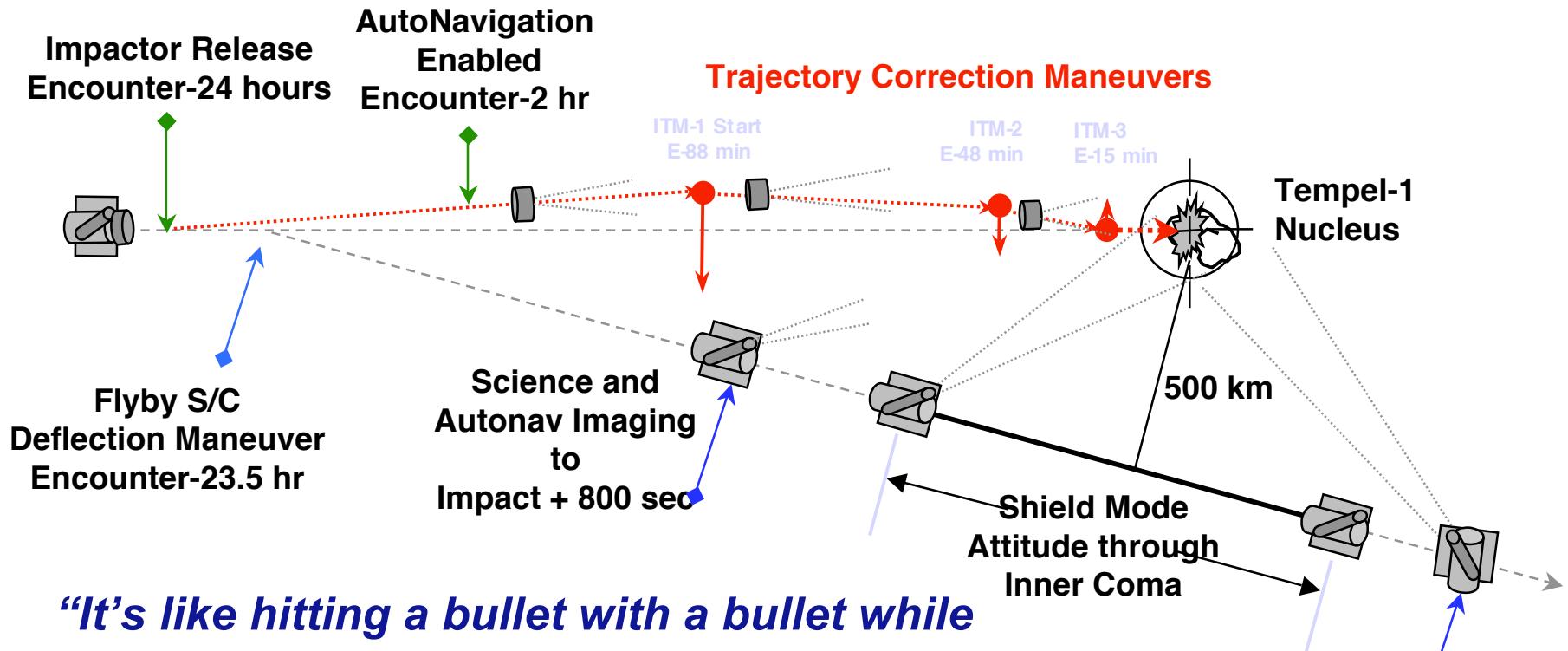
Impactor separates from
spacecraft 24 hours prior
to encounter -- Impact was
July 4, 2005



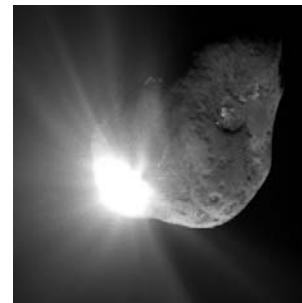


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Deep Impact Encounter Timeline



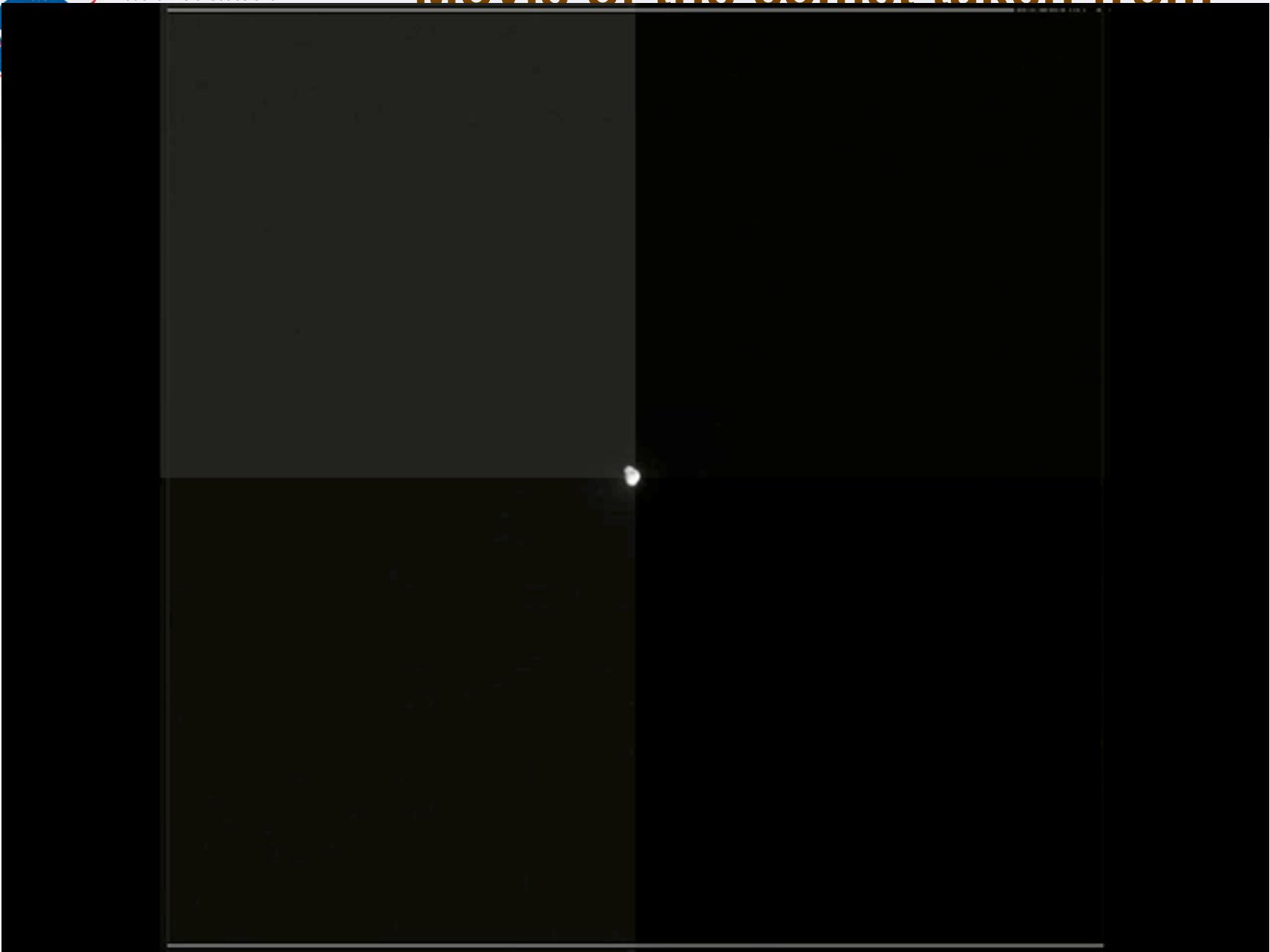
"It's like hitting a bullet with a bullet while you have a third bullet flying by trying to take pictures -- all at 30 times the speed of real bullets," said Rick Grammier, Deep Impact Project Manager





National Aeronautics and

Movie of the comet taken from





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NASA's Deep Impact tells a tale of a comet

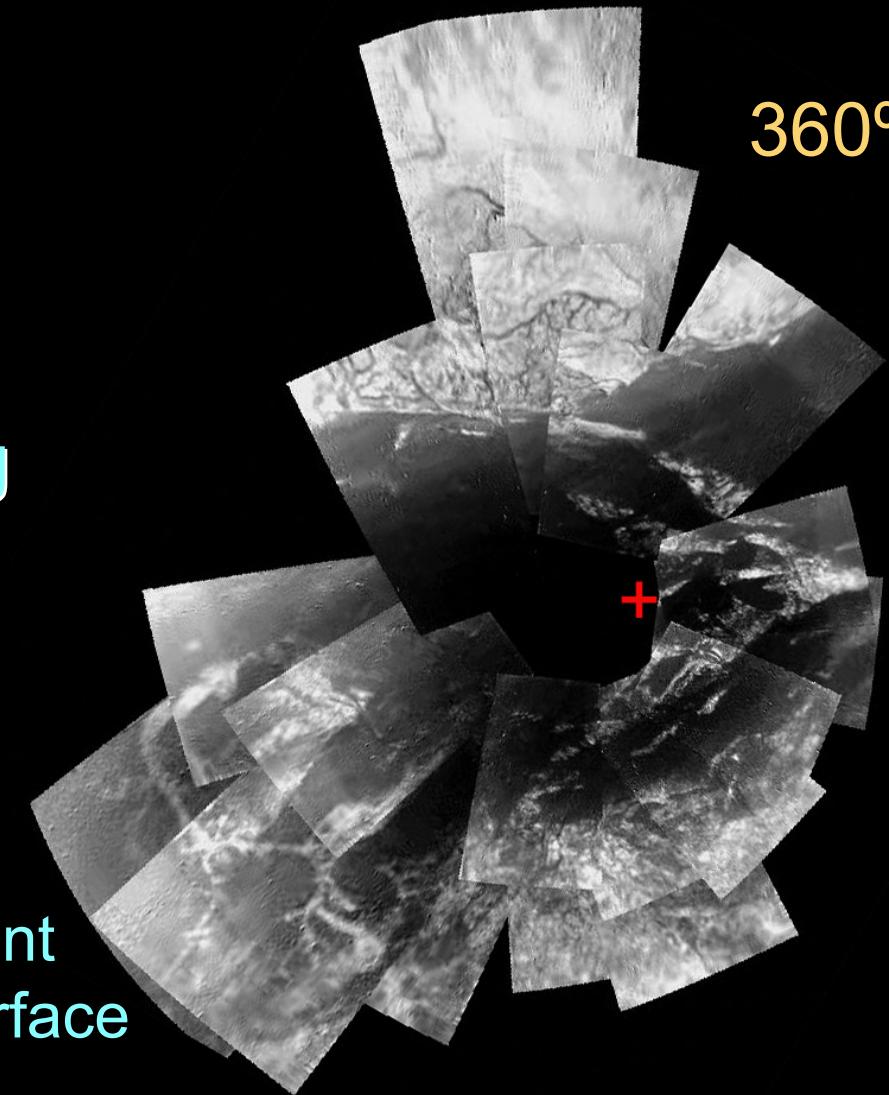
- Probe slammed into the nucleus of the comet at 6.3 miles per second and created an immense cloud of fine powdery material.
- "*That suggests the dust excavated from the comet's surface was extremely fine, more like talcum powder than beach sand. And the surface is definitely not what most people think of when they think of comets -- an ice cube,*" said Deep Impact Principal Investigator Dr. Michael A'Hearn of the University of Maryland, College Park.
- How can a comet hurtling through our solar system be made of a substance with less strength than snow or even talcum powder? "*You have to think of it in the context of its environment,*" said Pete Schultz, Deep Impact scientist from Brown University, Providence, R.I. "*This city-sized object is floating around in a vacuum. The only time it gets bothered is when the sun cooks it a little or someone slams an 820-pound wakeup call at it at 23,000 miles per hour.*"

Cassini Spacecraft Delivers ESA's Huygens Probe to Titan's Surface

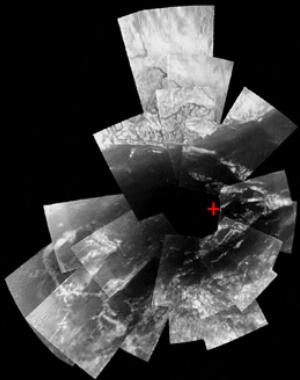
360° Panorama of landing spot

Images from Probe during descent

2h 27 m descent
1h 12 m on surface

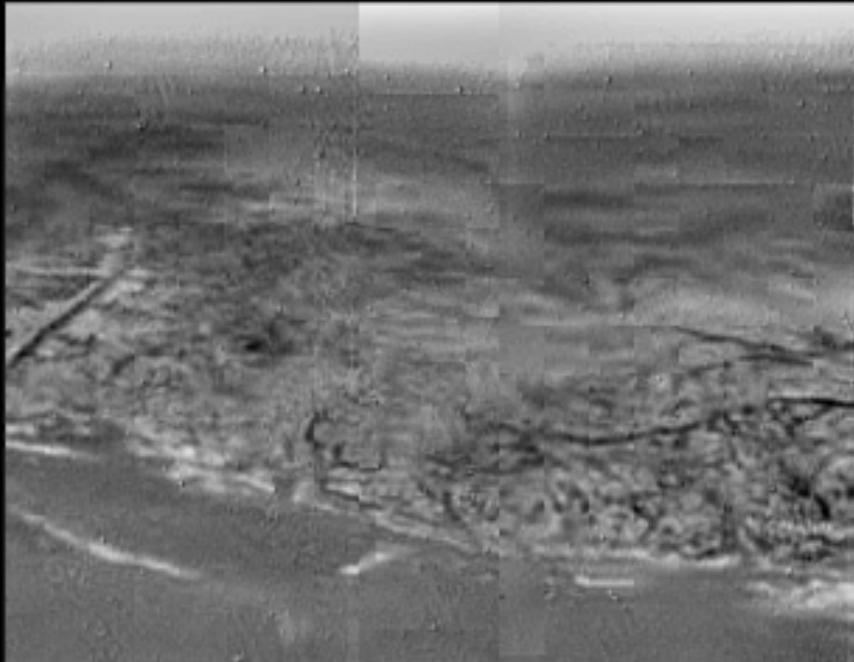


↔ ~25 km →

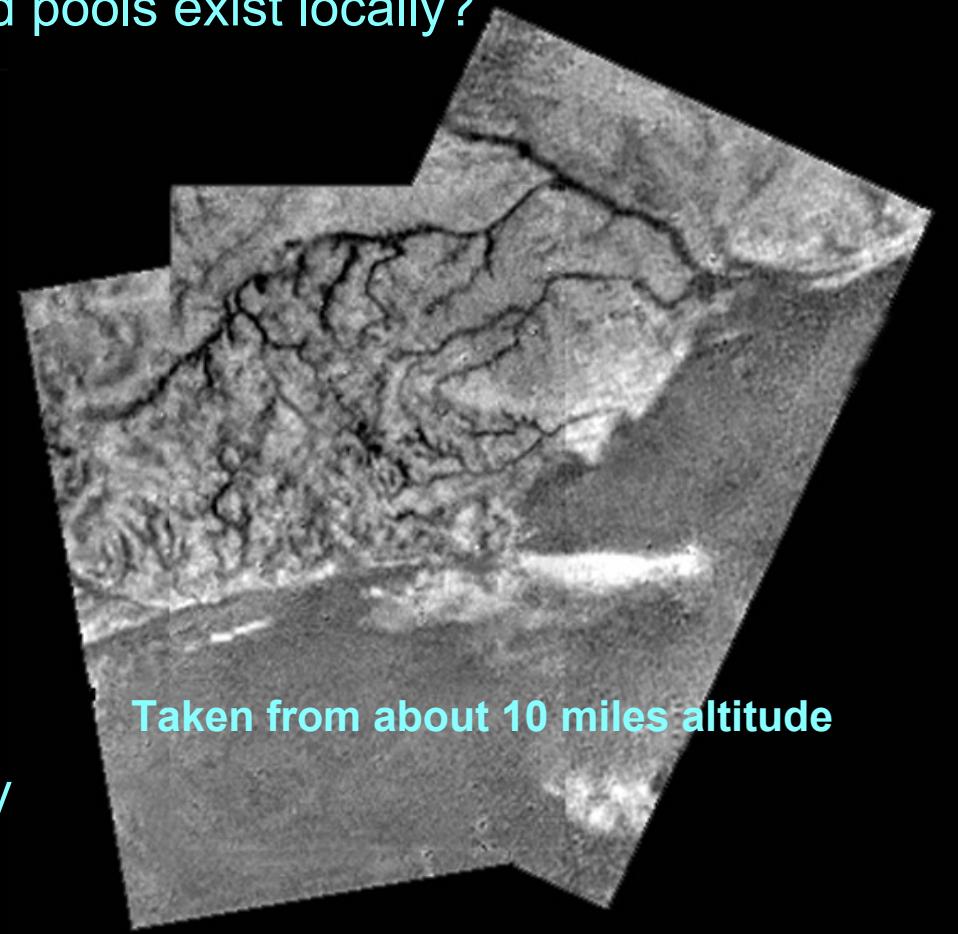


Images from Titan Probe showing flow into a major river channel from different sources---is methane rain required?

Are dark channel floors full of organic
sludge washed off the brighter highland?
Could liquid pools exist locally?

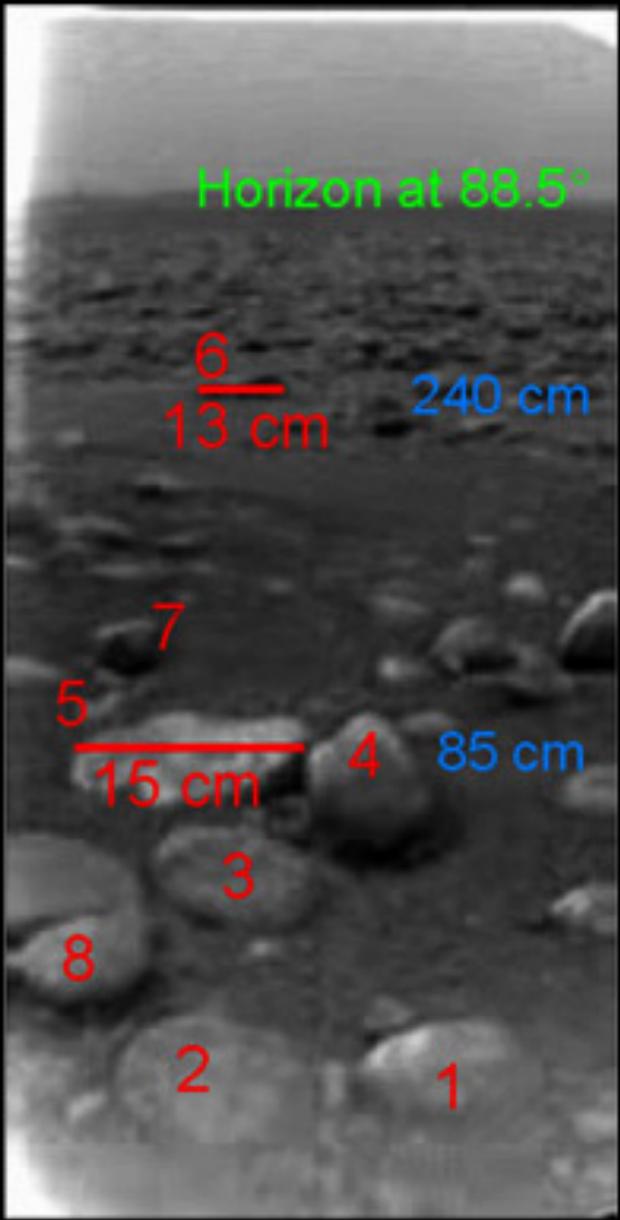


Early pre-biotic (before life) Earth may
have had an atmosphere like Titan's!



Taken from about 10 miles altitude

Titan's Surface!



The surface is darker than originally expected, consisting of a mixture of water and hydrocarbon ice.

There is also evidence of erosion at the base of these objects, indicating possible fluvial activity.

Cassini visits Saturn's Moon Enceladus, July 14 and finds an active, watery world

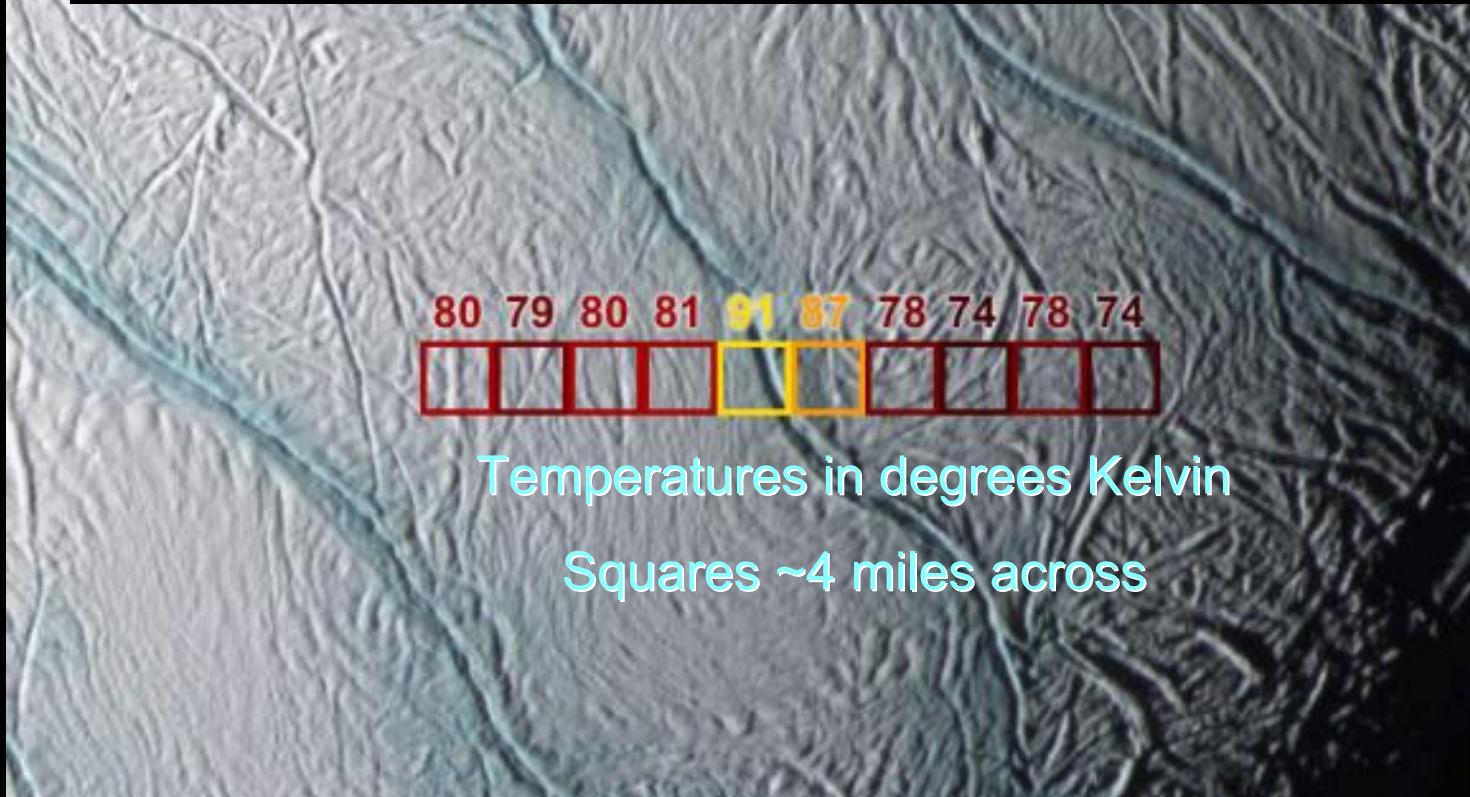
**Heavily
cratered
on top**

**175 km
flyby!!**



**Few craters on
bottom- evidence
for active ice
volcanism**

The Fractures are WARMER!



Cassini found a huge cloud of water vapor over Enceladus' south pole - probably supplied by ice evaporating from the warm fractures

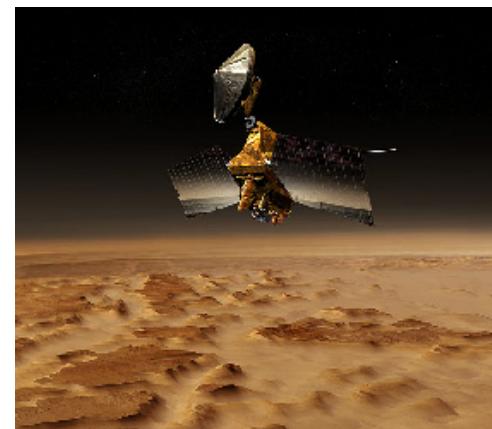


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Recent JPL events

- **April 2006: Cloudsat launch**
- **January 15, 2006: Stardust Earth landing- returning a sample of a comet's tail**
- **March 2006 - Mars Reconnaissance Orbiter arrives and begins aerobraking (launched August 12)**



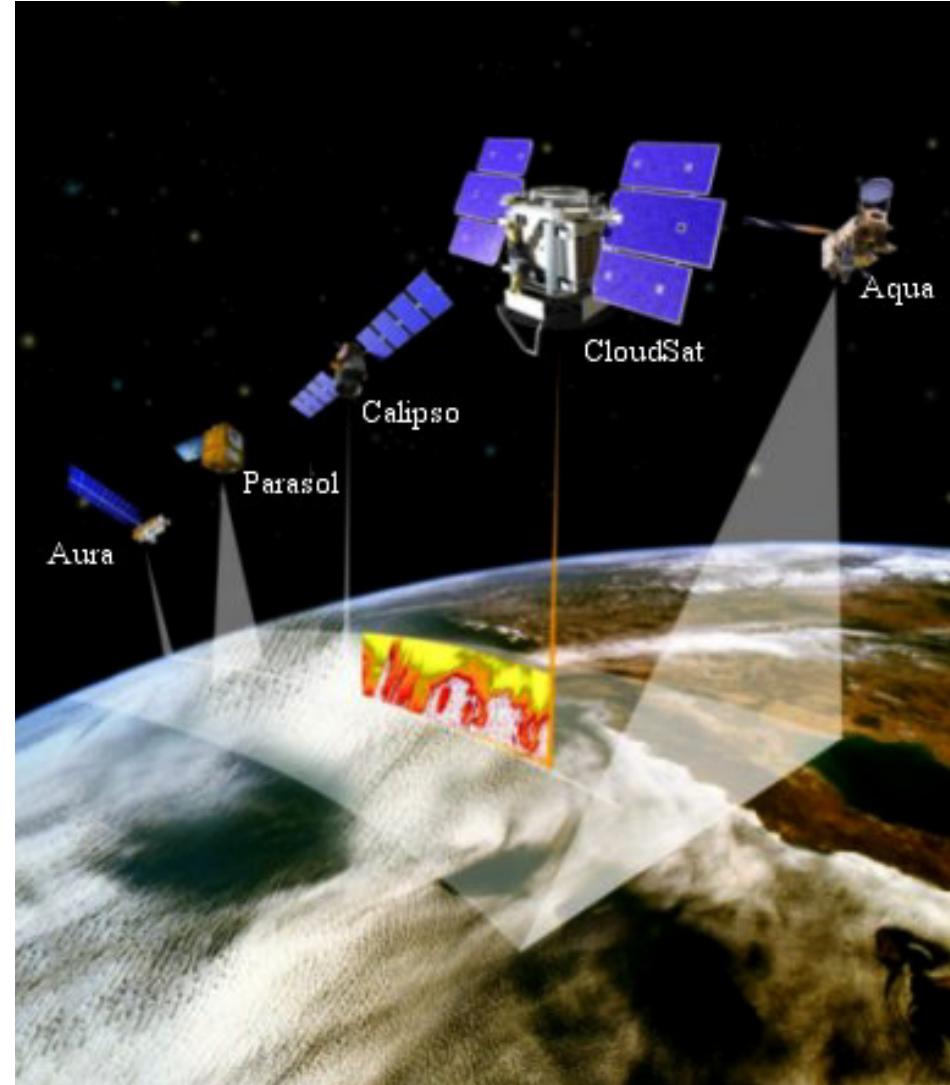


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Cloudsat Launched on April 28, 2006

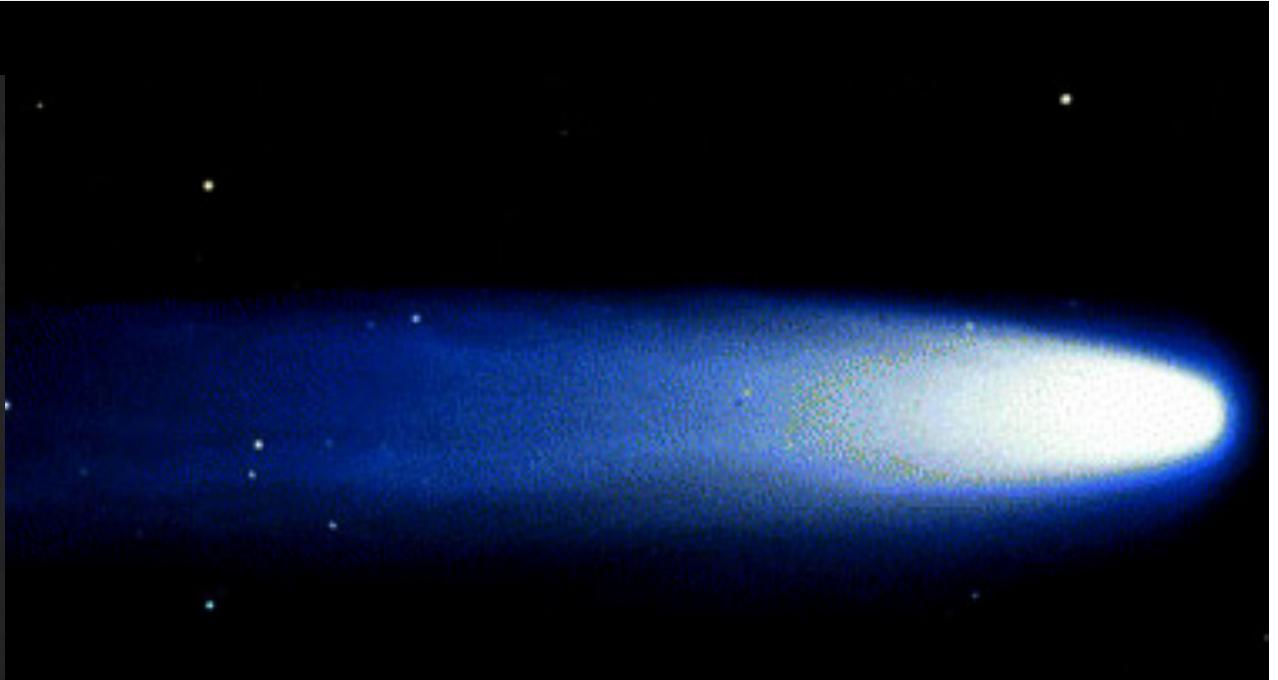
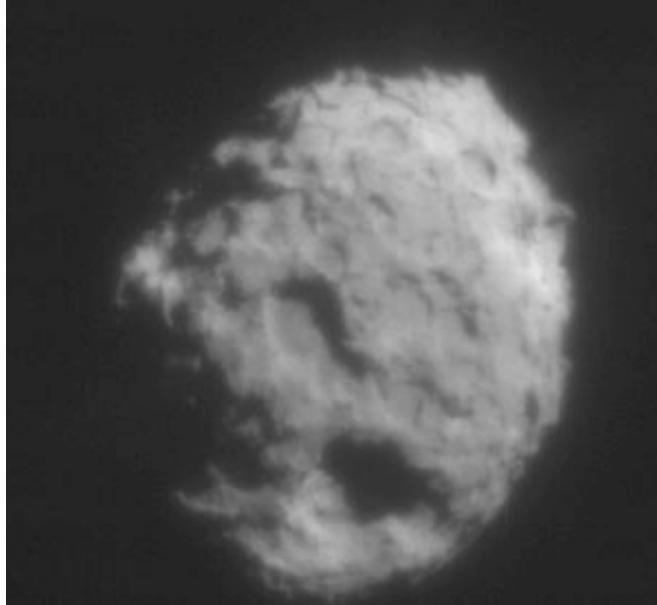
- Measure vertical structure of clouds, and cloud properties using 94GHz profiling radar.
- Quantify global and seasonal variations of clouds.
- Relate clouds to Earth's energy budget.
- Fly in formation with Aura, Parasol, Calypso, and Aqua.





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Stardust returned first sample of a comet to Earth



**On January 2, 2004, Stardust flew within
236 kilometers of Comet Wild 2 and
captured thousands of particles in its
aerogel collector for return to Earth on
January 15, 2006
NASA's Stardust sample return capsule
successfully landed at the U.S. Air Force
Utah Test and Training Range at 2:10 a.m.**



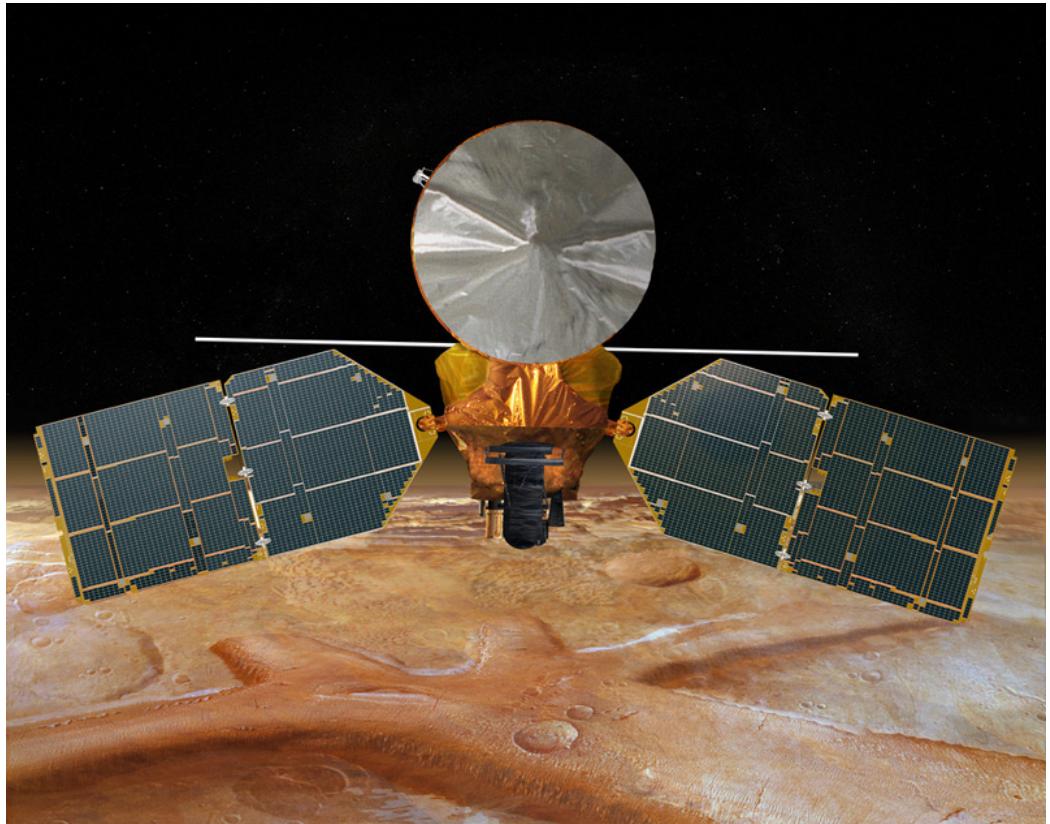


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Mars Reconnaissance Orbiter

Arrived at Mars in March 2006

- **Study history of water on Mars.**
- **Seek evidence of sub-surface water.**
- **Seek water-formed minerals.**
- **Study atmospheric dust and water distribution.**
- **Monitor daily global weather.**
- **5.6 Mb/s maximum data rate enables 1 meter resolution over large areas.**





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JPL science missions under development for launch 2007–2011

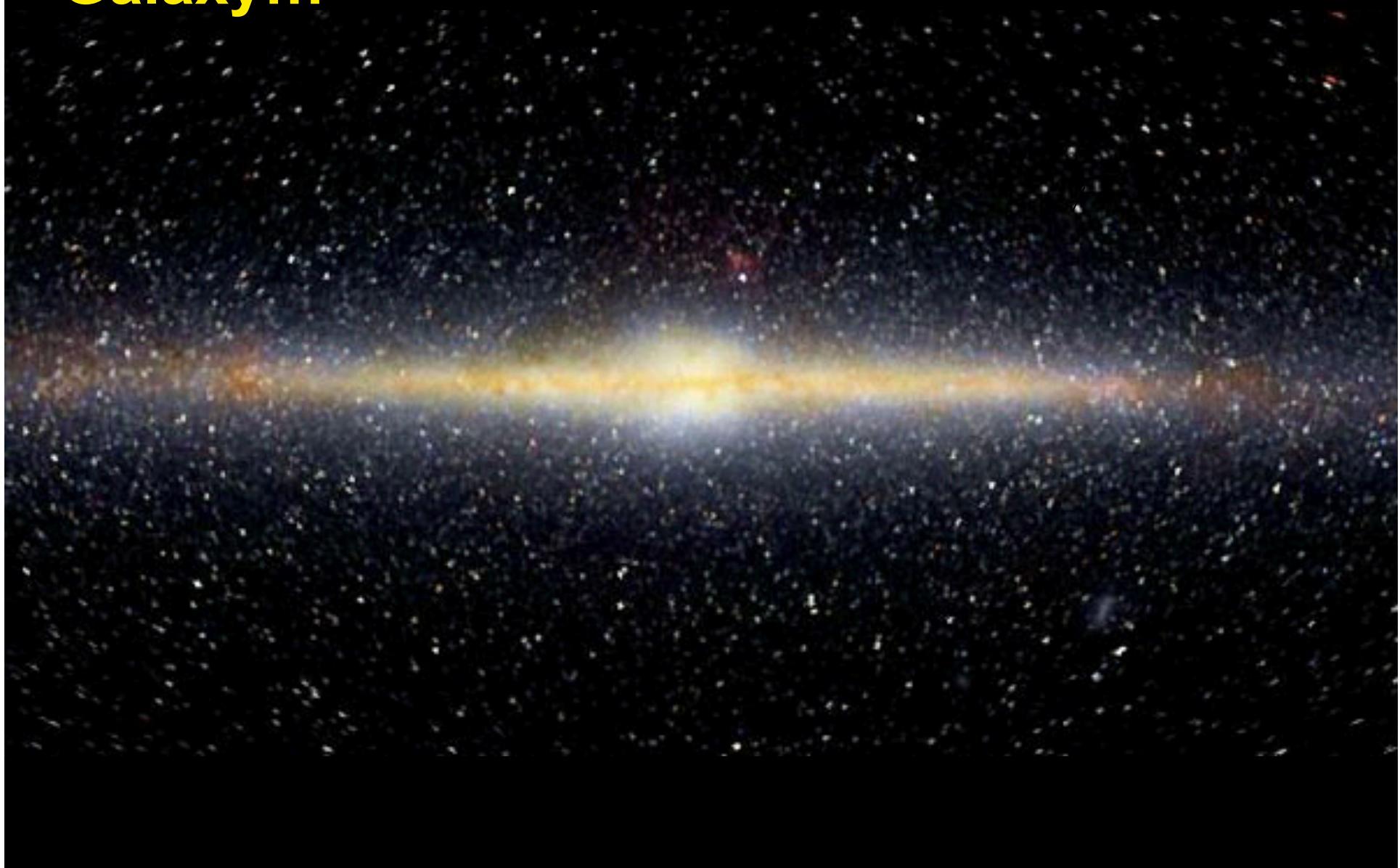
- *Dawn*: June 07
- *Kepler*: Jun 08
- *Phoenix*: Aug 07
- *Orbiting Carbon Observatory*: 08
- *Ocean Surface Topography Mission*: 08
- *Wide-Field Infrared Survey Explorer (WISE)*: 09
- *Aquarius*: 09
- *Mars Science Laboratory*: 09
- *NUSTAR (Nuclear Spectroscopic Telescope Array)*: 10
- *Space Interferometer Mission (SIM)*: 10-11
- *Juno* : 10-11



Exploring Our Home Planet



**A Typical Star in a Typical
Galaxy...**

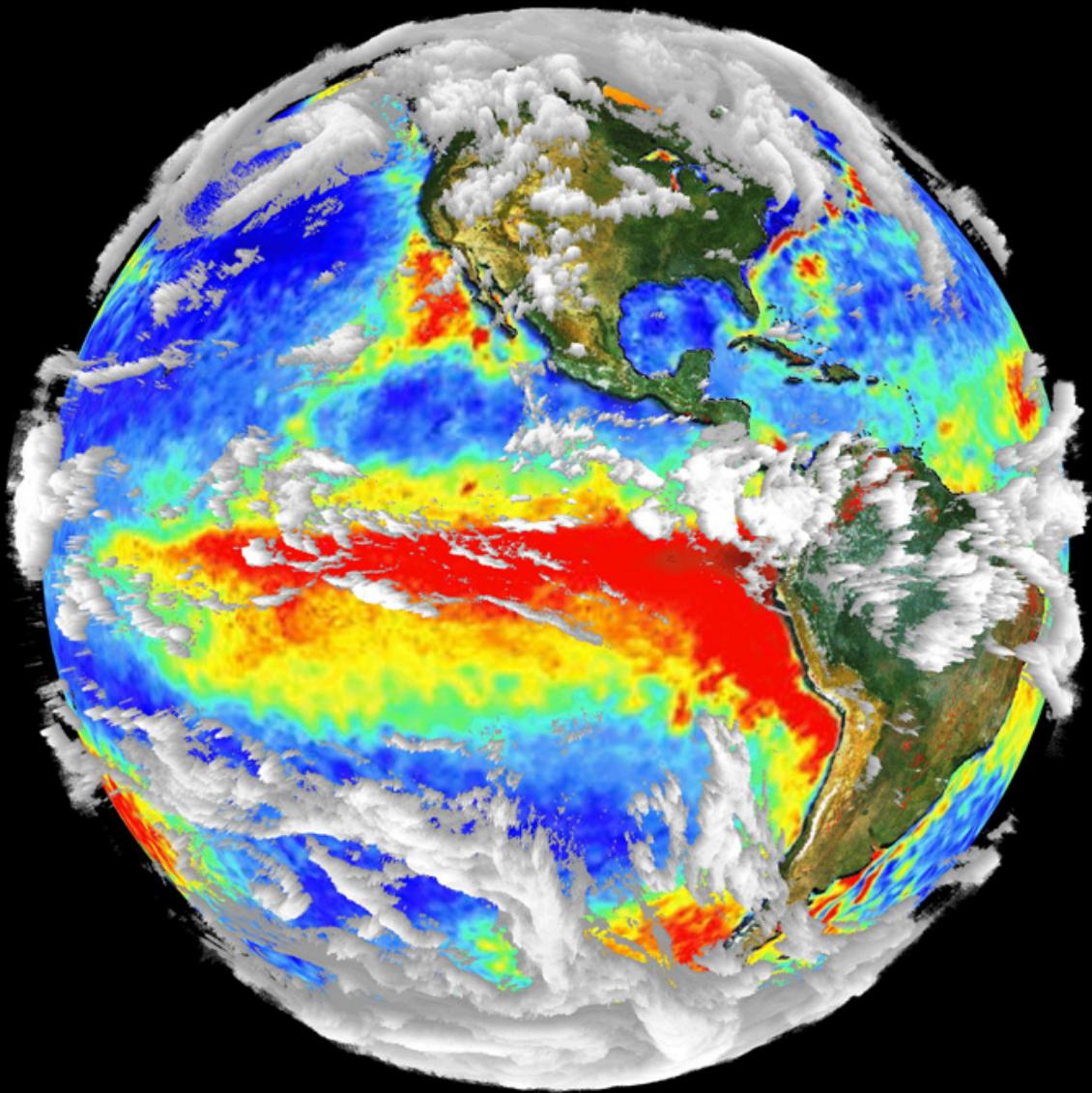




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...but the only known harbor for life in the universe

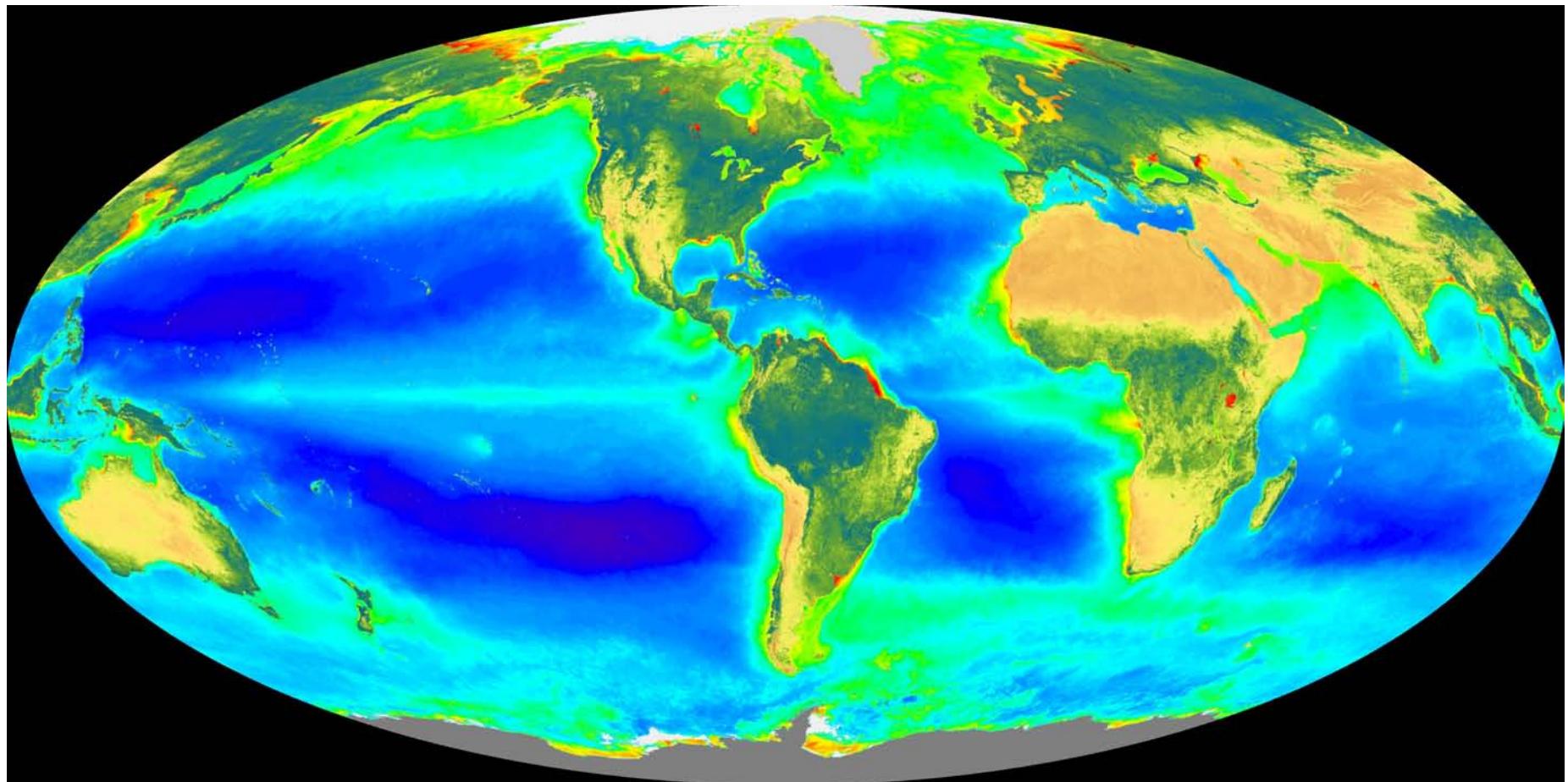
A Stable Climate is Conducive to Life





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A Carbon Cycle Implies a Biosphere

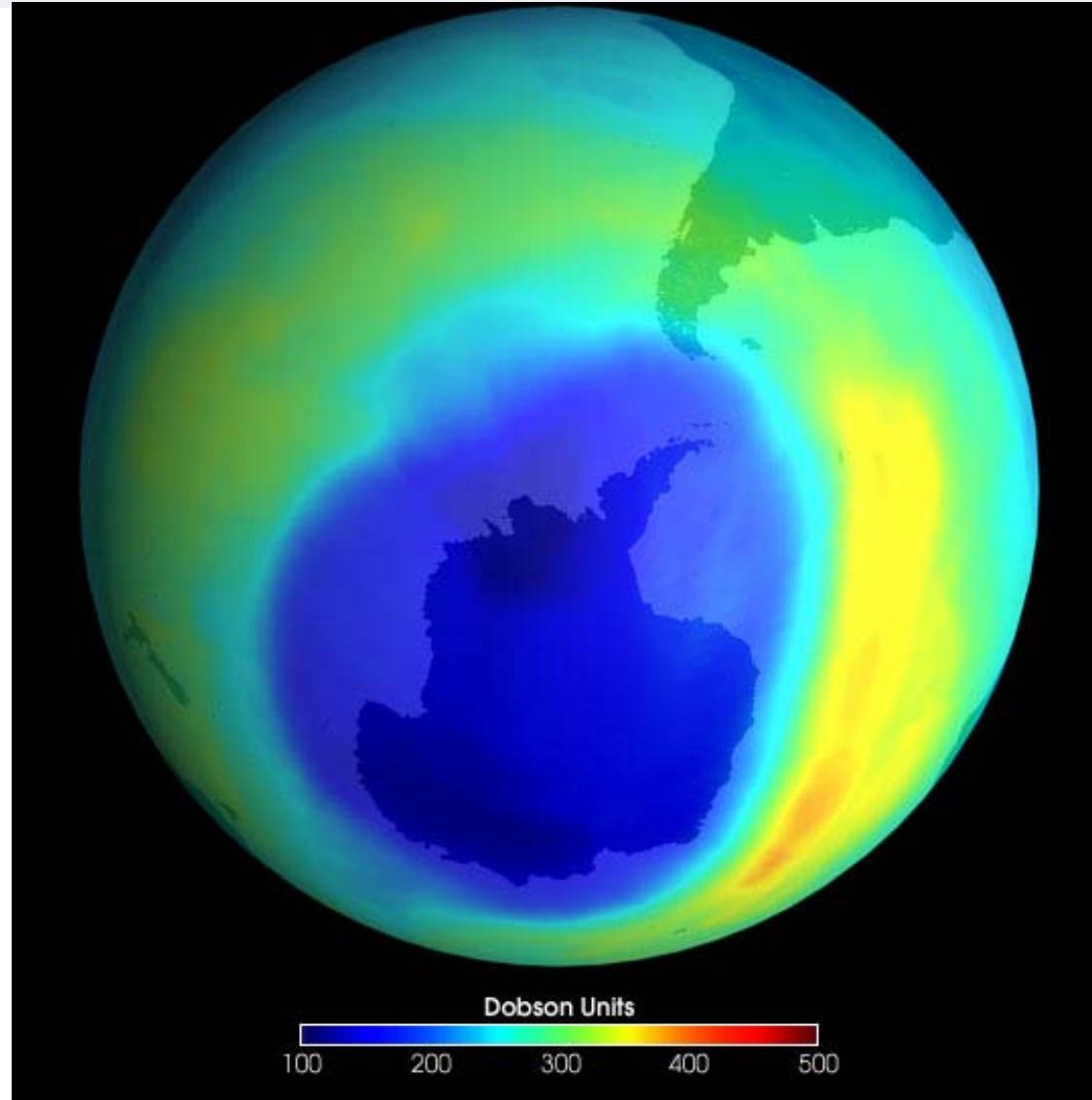




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Atmospheric Chemical Composition Could Be an Indicator of Intelligent Life

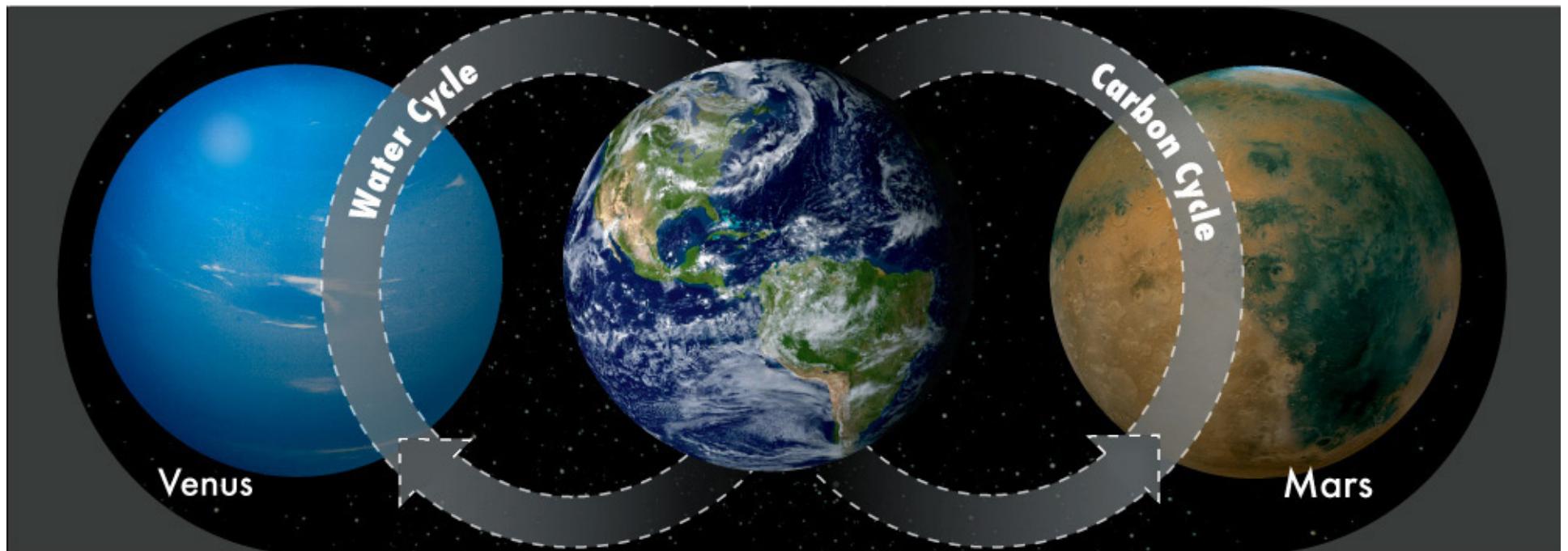




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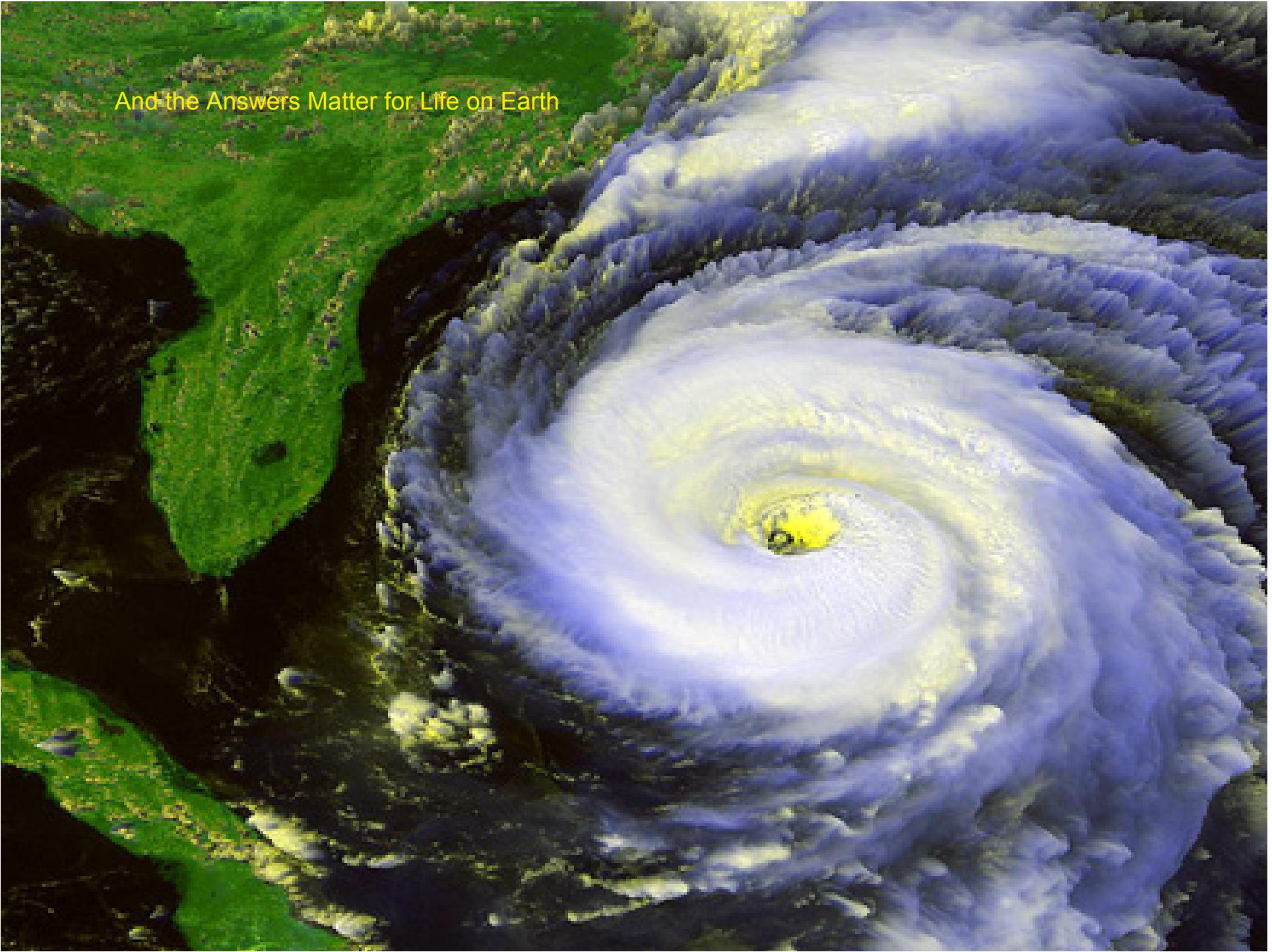
NASA is in the Business of Studying Planets



- Runaway greenhouse ::
No water cycle to remove
carbon from atmosphere

Earth
Harbor of Life

- Loss of carbon ::
No lithosphere motion on
Mars to release carbon



And the Answers Matter for Life on Earth



Earth System Science

Sun-Earth
Connection

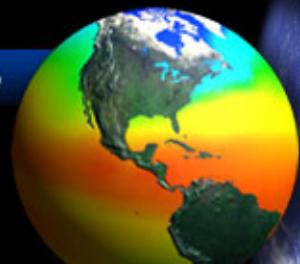
Climate Variability
and Change

Earth Surface
and Interior

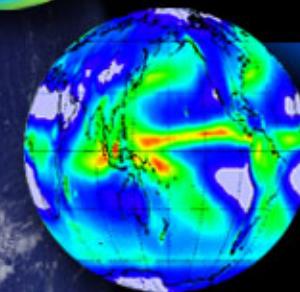
Carbon Cycle
and Ecosystems

Atmospheric
Composition

Weather



*How is the Earth
changing and what
are the
consequences for
life on Earth?*



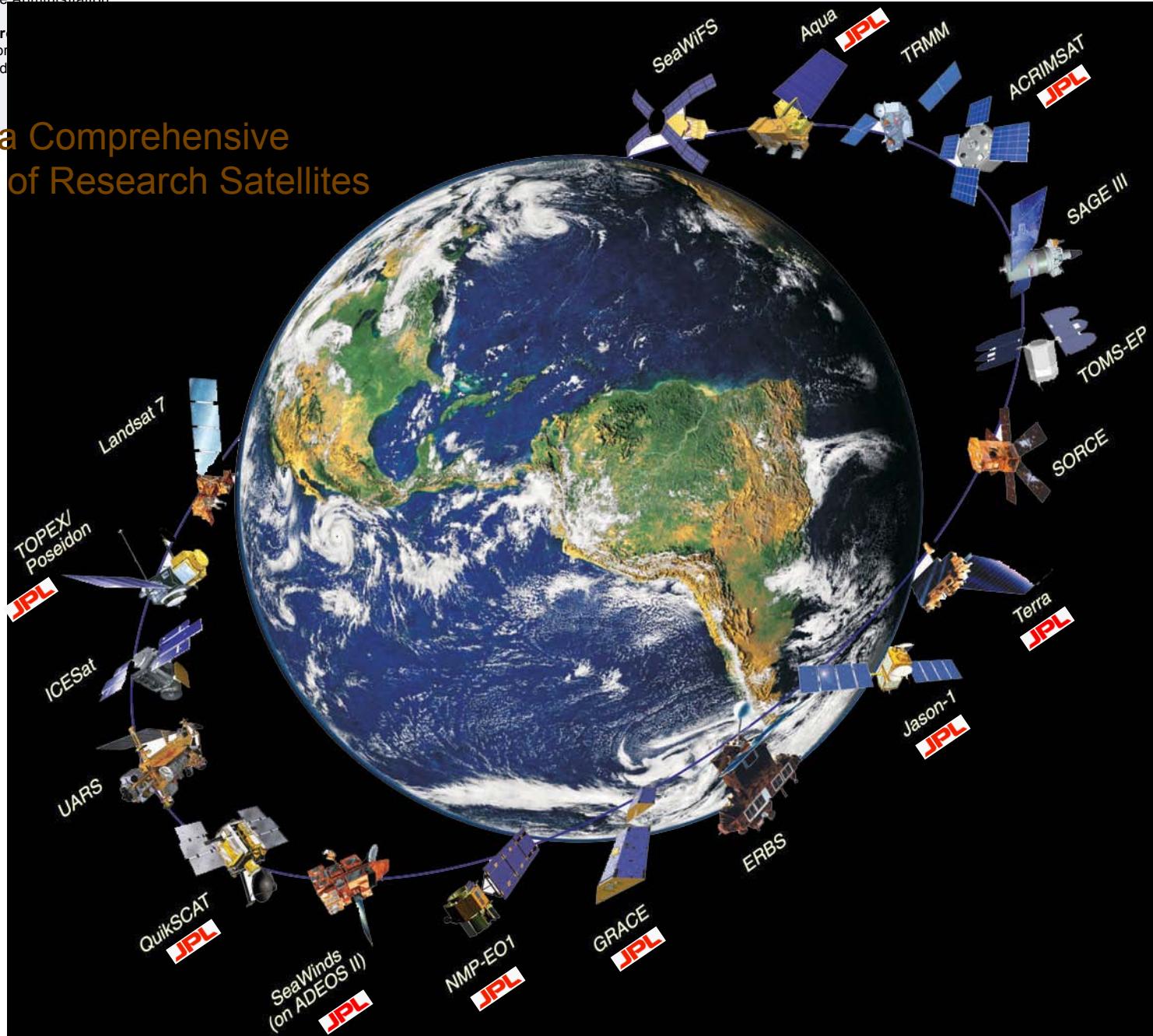
Water &
Energy
Cycle



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Toward a Comprehensive Constellation of Research Satellites



6/25/07



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Missions to Enable Ocean Science

TOPEX/Poseidon & Jason-1

provide global views of El Niño/La Niña Pacific Decadal Oscillation, and sea level rise



SeaSAT
(1978)



TOPEX /
Poseidon
(1992-Present)



NSCAT
(1996)

SeaWinds

increases prediction time for hazardous weather events over oceans by 6-12 hours

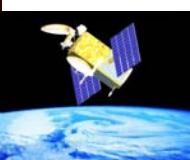


QuikSCAT
(1999-Present)

Topex / Poseidon and Jason-1 Tandem
(2002-Present)



SeaWinds
on
Midori-II
(2002-2003)



Ocean Surface Topography Mission
(2008)



Aquarius
(2009)



Wide Swath
Ocean
Altimeter
(TBD)



Ocean
Vector
Winds
Mission
(TBD)

OSTM/Jason-2
will
discriminate
mesoscale
ocean features

Aquarius
OVWM
will improve
climate models



6/25...



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Missions to Enable Atmospheric Science

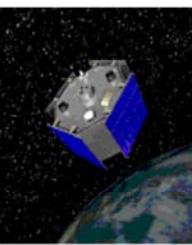
ATMOS & MLS
were instrumental
in understanding
ozone depletion



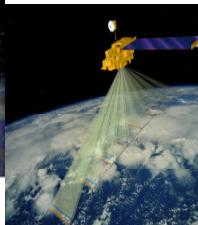
ATMOS
(1985)



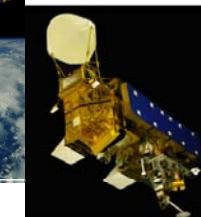
UARS MLS
(1991-
Present)



ACRIMSAT
(1999-
Present)



MISR on
TERRA
(1999-
Present)



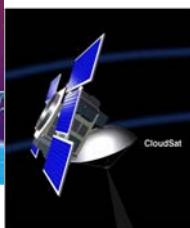
AIRS on
AQUA
(2002-
Present)



TES on AURA
(2004-Present)



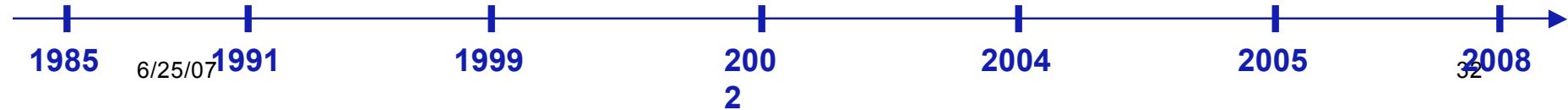
MLS on
AURA
(2004-
Present)



CloudSat
(2006)



**Orbiting Carbon
Observatory
Mission**
(2008)





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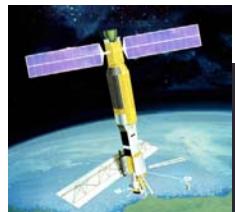
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Missions to Enable Solid Earth and Hydrology Science

SIR

series

demonstrated the
most advanced
radar technology
ever flown



SeaSAT
(1978)



SIR-A
(1981)



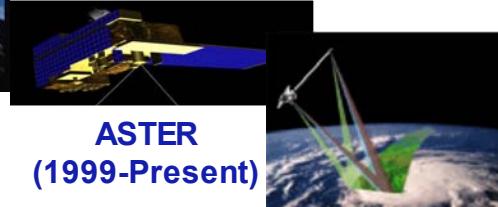
SIR-B
(1984)

SRTM

data were used to
create the most
accurate and
highest resolution
global topographic
map



SIR-C
(1994)



ASTER
(1999-Present)

GRACE

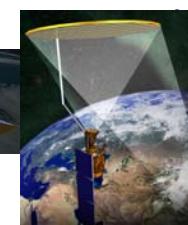
has improved
our estimates
of Earth's
gravity by a
factor of 50-
100X



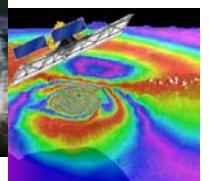
GRACE
(2002-Present)

SMAP

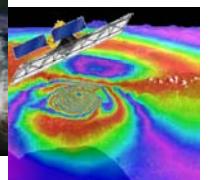
will improve
estimates of
the
hydrologic
cycle



DESDynI
will improve
our
understanding
of earthquakes
volcanoes



Hydros
(TBD)



InSAR
(TBD)



1978 6/25/07 1981

1984

1994

1999

2000

2010

33

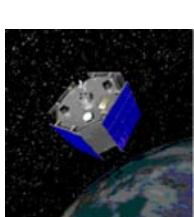


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Current JPL Earth Science Flight Projects

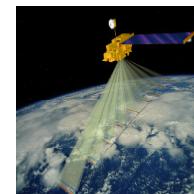
Operational



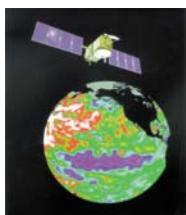
ACRIMSAT
(1999)



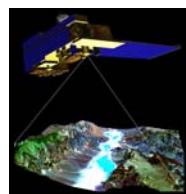
QuikSCAT
(1998)



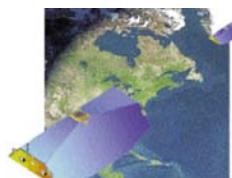
MISR
(1999)



Jason-1
(2001)



ASTER
(1999)



GRACE
(2002)



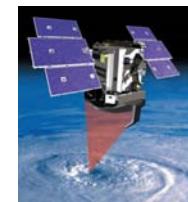
TES
(2004)
6/25/07



AIRS
(2002)

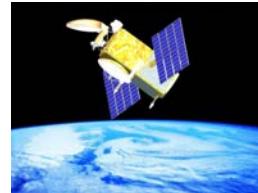


MLS
(2004)



CloudSat
(2006)

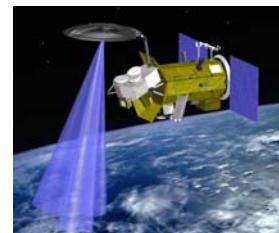
Development



**Ocean Surface
Topography Mission**
(2008)

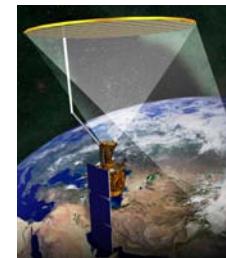


**Carbon Cycle:
Orbiting Carbon
Observatory (OCO)**
(2008)

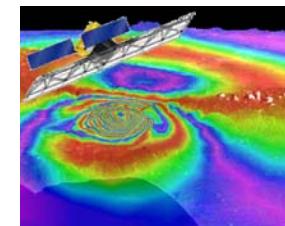


**Sea Surface
Salinity:
Aquarius**
(2009)

Formulation/pre-formulation



**Global Soil
Moisture
(Hydros)**



L-Band InSAR



**Ocean
Vector Wind
Mission**
(NOAA)

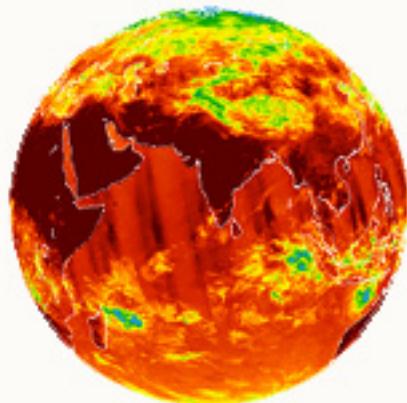


**Sea Surface &
Terrestrial Water Levels**
(NASA, NOAA, Navy)

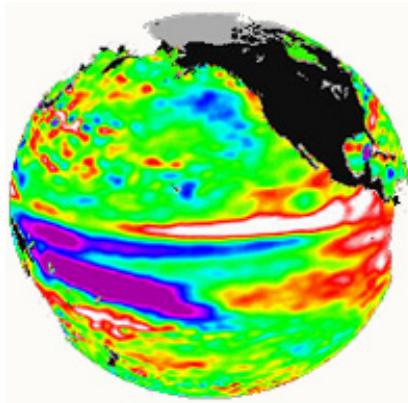


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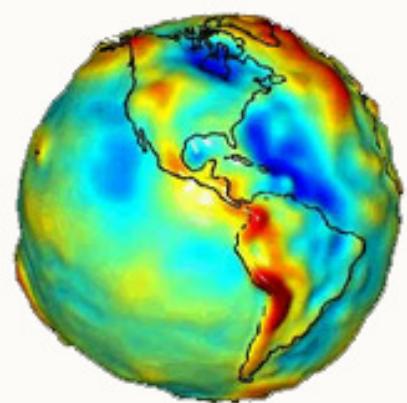
JPL is Providing New Ways to See the Earth and it's Changing Climate



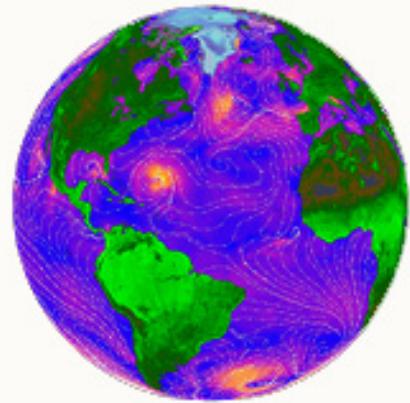
Atmospheric Infrared Sounder (AIRS) provides monthly global temperature maps



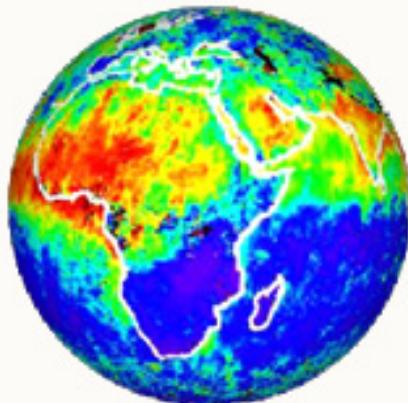
Jason provides global sea surface height maps every 10 days



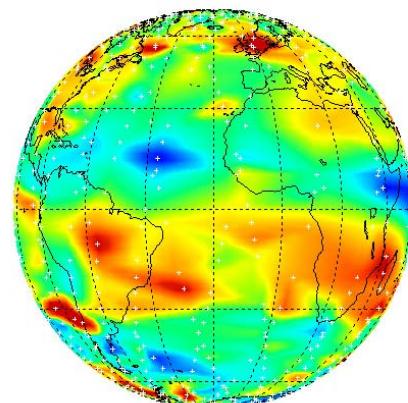
Gravity Recovery and Climate Experiment (GRACE) provides monthly maps of Earth's gravity



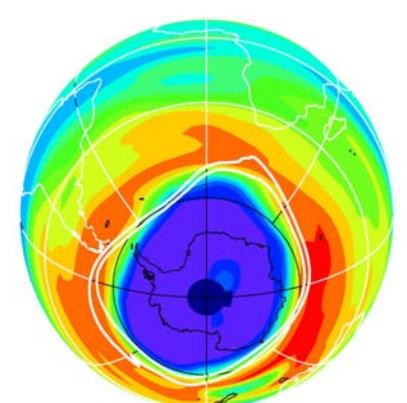
QuikSCAT provides near global (90%) ocean surface wind maps every 24 hours



Multi-angle Imaging Spectro Radiometer (MISR) provides monthly global aerosol maps



Tropospheric Emission Spectrometer (TES) provides monthly global maps of Ozone

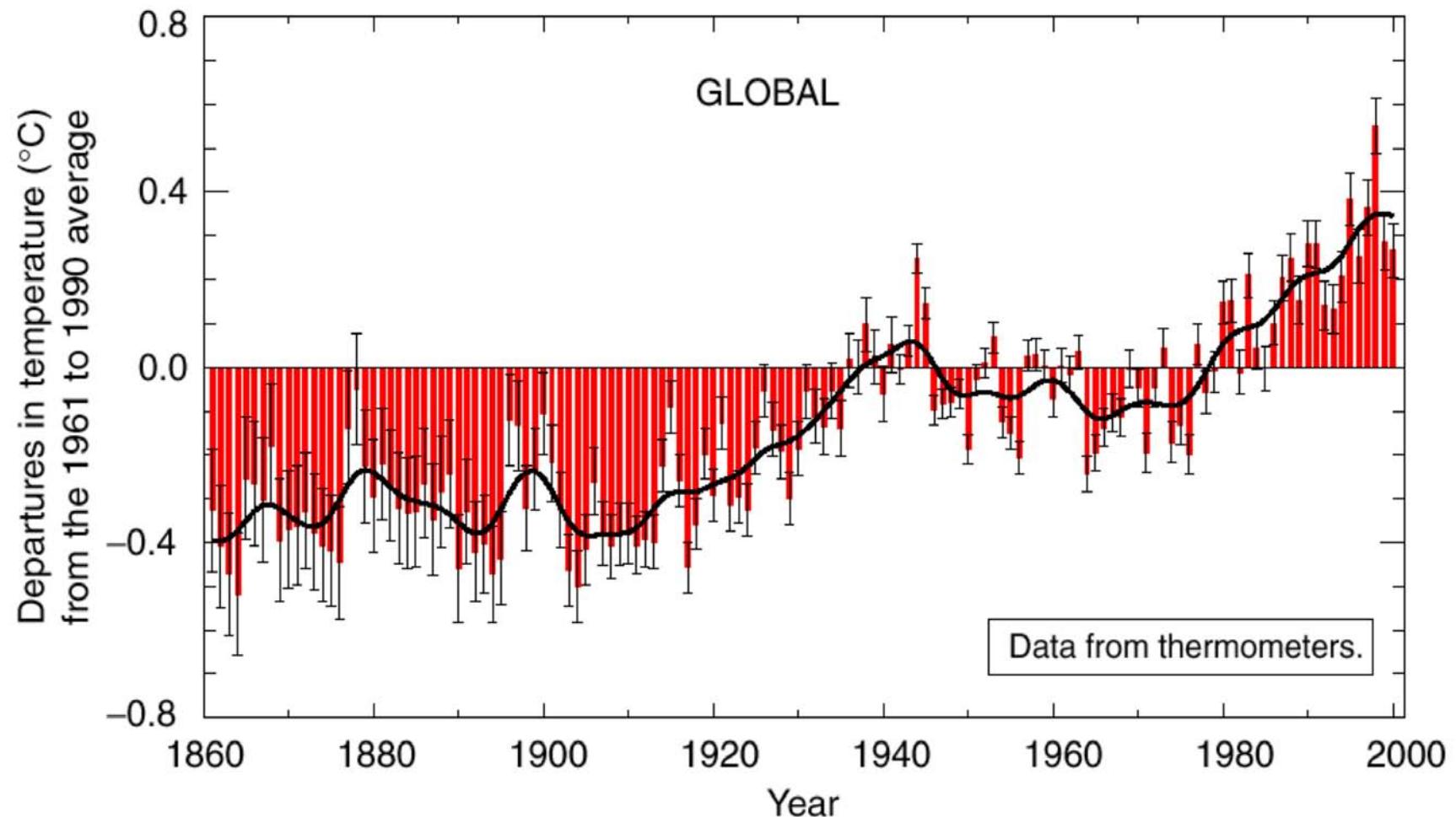


Microwave Limb Sounder (MLS) provides daily maps of stratospheric chemistry



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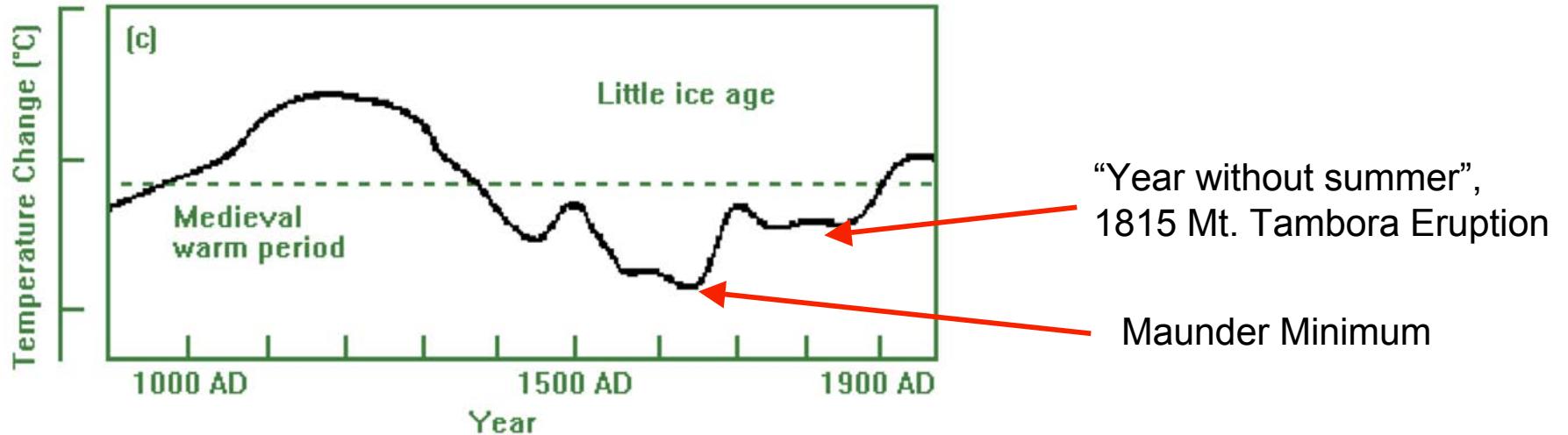
Surface thermometers record global rise





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Even small changes are important



Washington's 1776 crossing of an ice covered Delaware River (Leutze, 1851)





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At present glaciers are receding

1928



Photographed in 1928

2000



Photographed in 2000

South Cascade Glacier, Washington



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The Arctic sea ice is shrinking and thinning



1979



~ 20% decrease

Sea Ice Minimum 2005

2005





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Recent JPL Earth Science Highlights

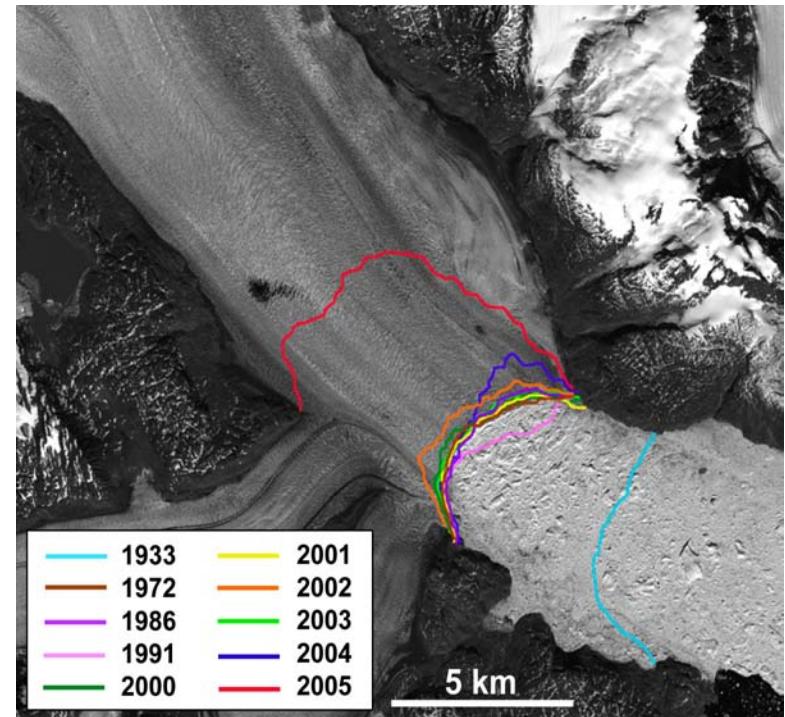
East Greenland Glacier Flow from ASTER

Similar responses at nearly coincident times implies that climate change is common trigger mechanism

Acceleration of Greenland glacier flow causes estimate of it's contribution to global sea level rise to increase to ~20%

Other outlet glaciers in Greenland might exhibit similar responses as climate change effects migrate northwards

Kangerdlugssuaq Glacier

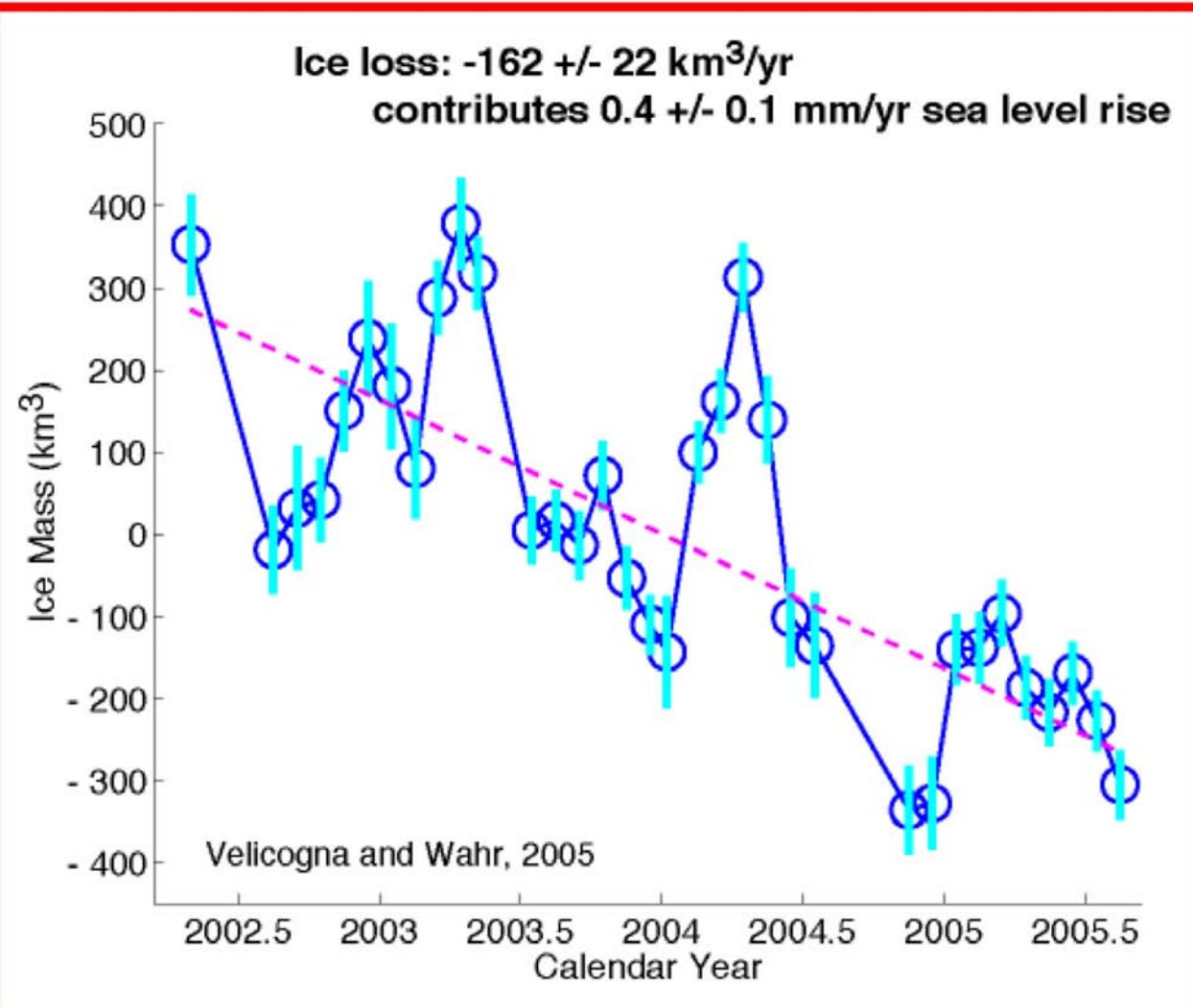


~300% flow speed acceleration



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Recent JPL Earth Science Highlights



6/25/07

41

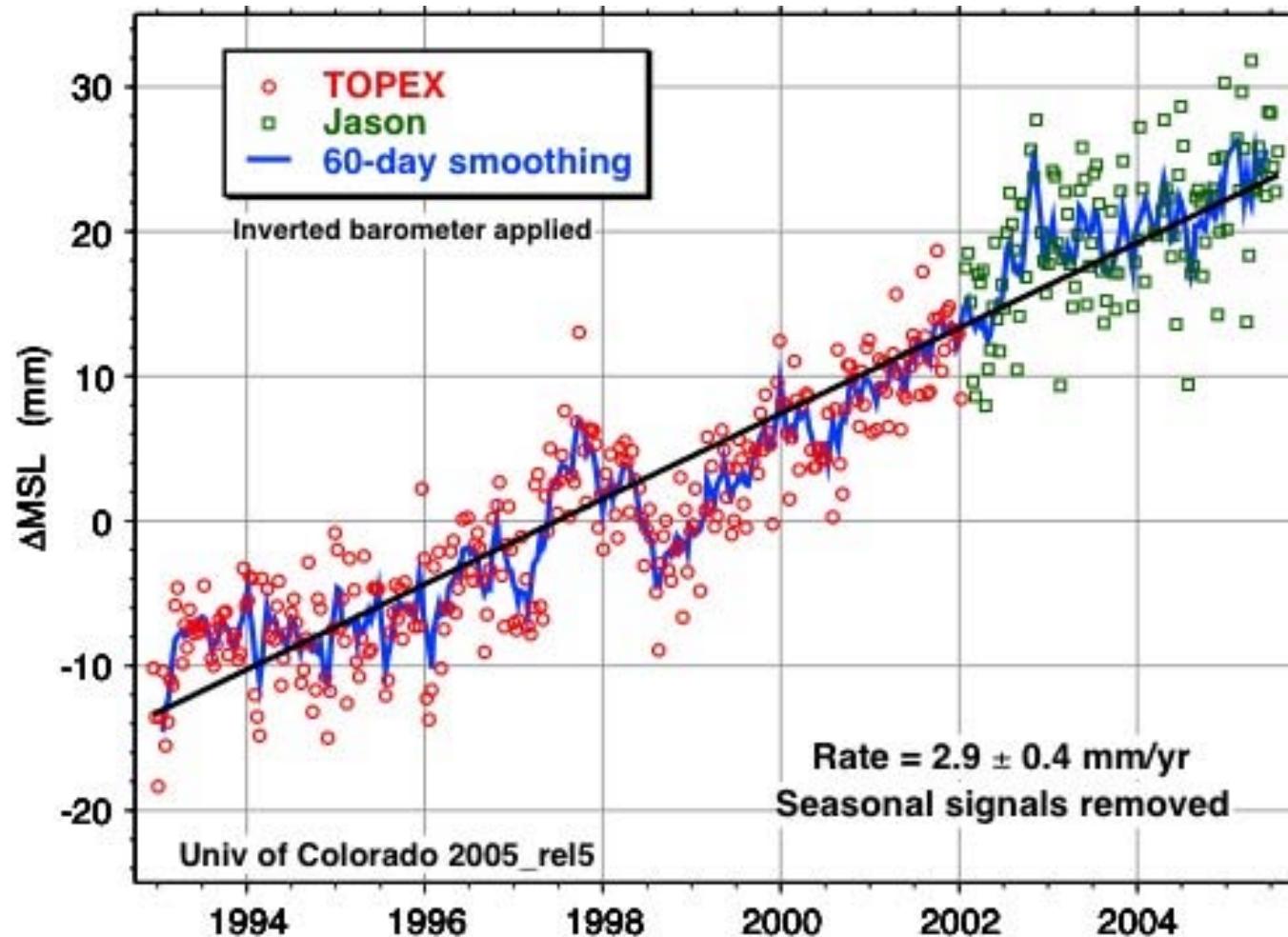
GRACE measurements show mass loss in Greenland



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Recent JPL Earth Science Highlights

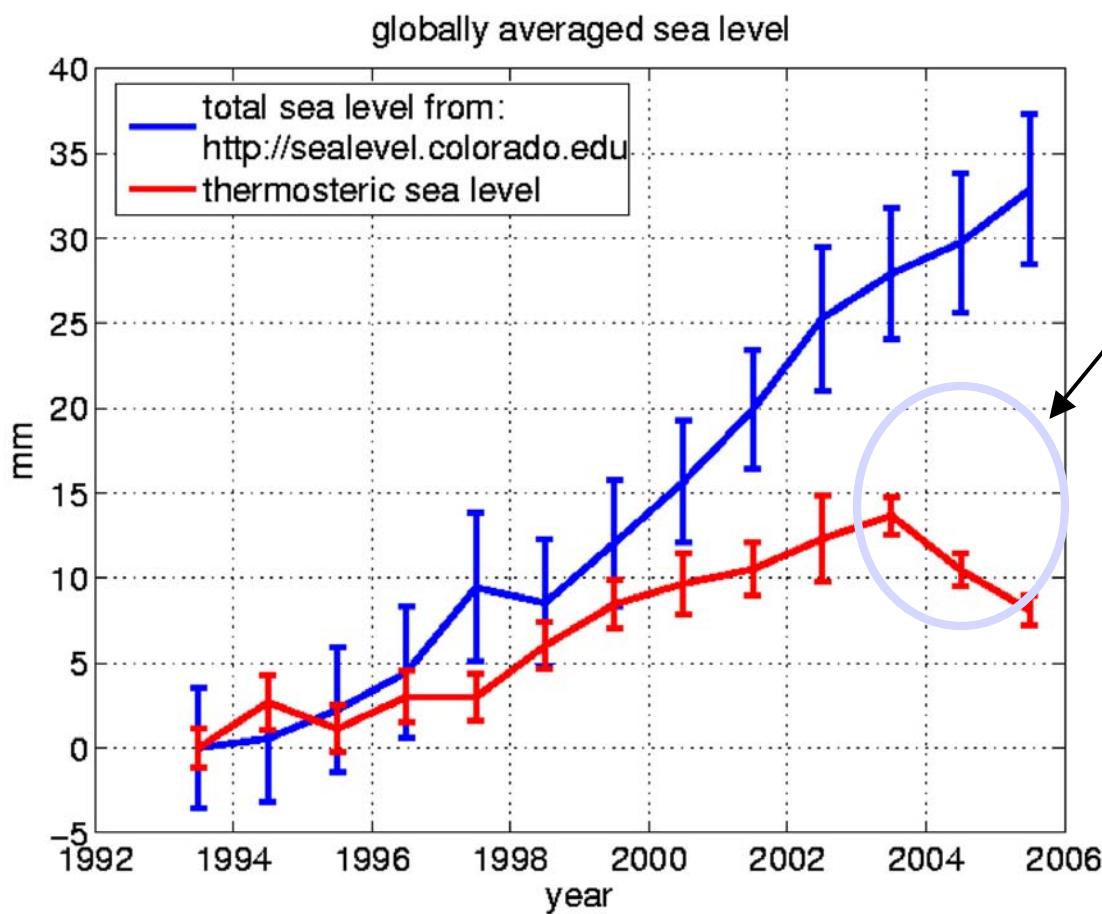


Global average sea level rise from TOPEX-Poseidon and Jason-1 data



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A Cooling Ocean: Implications for Climate Change?

Result:

- Globally averaged temperature of the upper 750 m of the ocean decreased between 2003 and 2005

Implications:

- Possible net loss of heat from Earth to space,
- Decrease in thermal expansion of sea level,
- Increase in fresh water input into the ocean



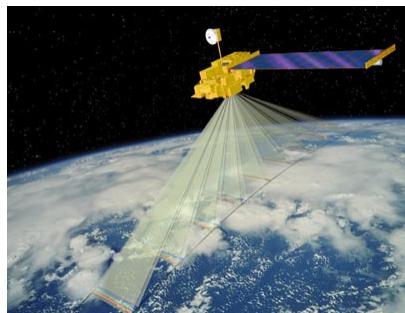
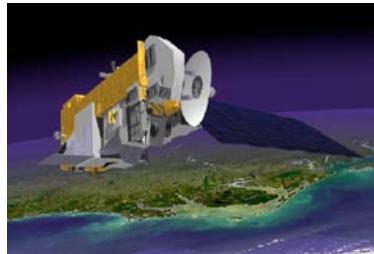
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Science for Society Example: JPL Optical Technology Enables Air Quality and Climate Research

By precisely measuring gas and particle concentrations we can understand the sources, sinks and transformations of urban pollutants

Gas and Particle Concentrations



Pollutant Data



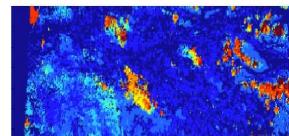
MISR's nadir (AN) camera shows three distinct smoke plumes, plus scattered smoke and clouds, over Alaska and Canada in the summer of 2004.



In white, smoke pixels detected by the Support Vector Machine classifier, which uses five of MISR's nine cameras to detect smoke using color, texture, and angular features.

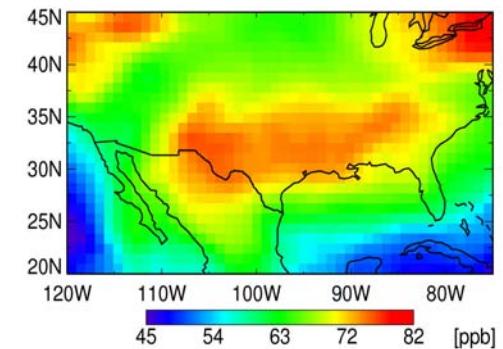


MODIS fire detections overlaid on the MISR image in red (high confidence) and yellow (low confidence).



Examining the height of each MISR pixel determined by automatic stereo pattern matching allows us to estimate the injection height of the smoke plumes.

Air Quality Predictions



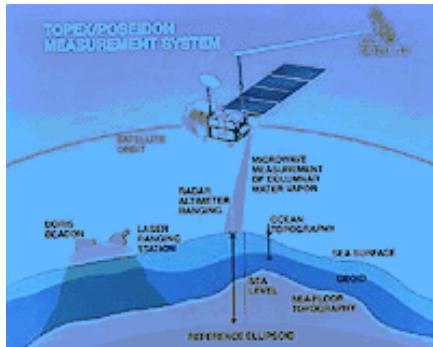


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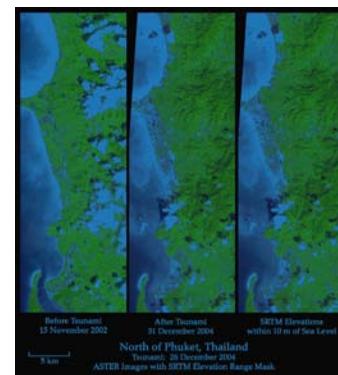
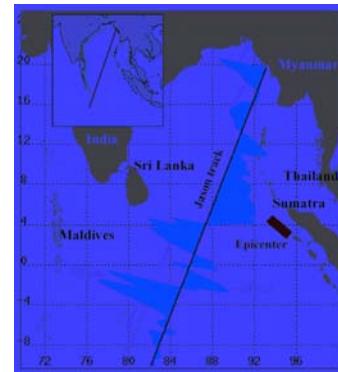
Science for Society Example: JPL Radar and GPS Technology Enables Future Tsunami Research

By precisely measuring seismic activity, coastal land topography, and small changes in sea level we can better understand tsunamis

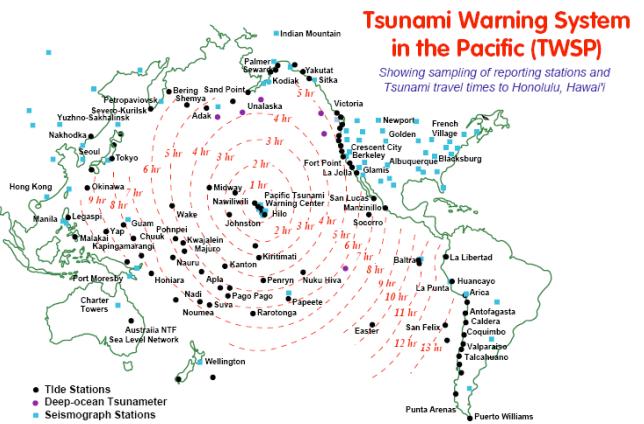
Ocean Altimetry Measurements



Tsunami Propagation Data



Improved Planning





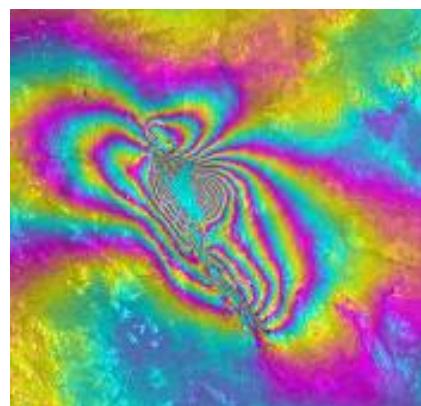
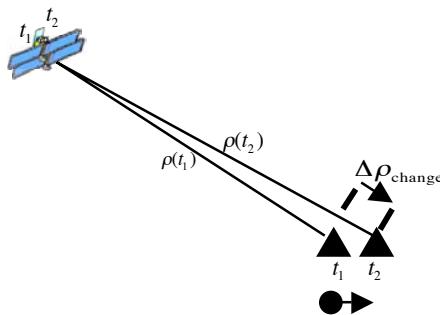
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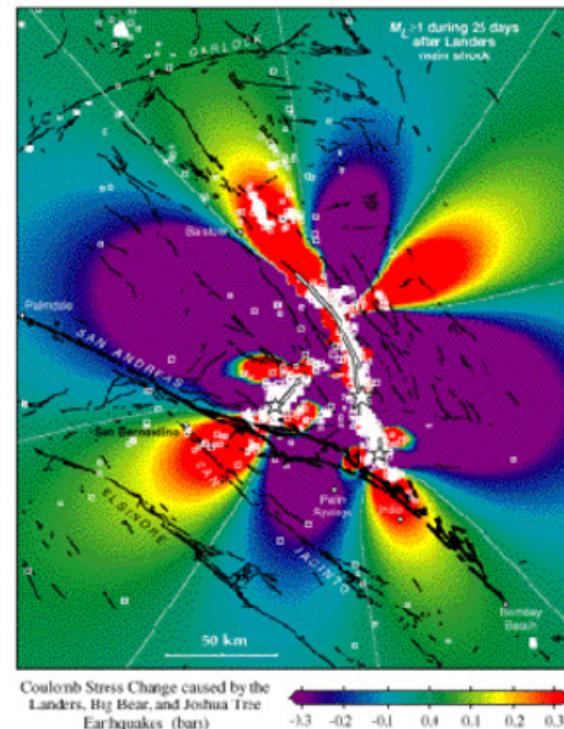
Science for Society Example: JPL InSAR Technology Enables Future Exploration of Earth's Surface

By precisely measuring small changes in Earth's surface, we can infer the subsurface behavior that leads to seismic and volcanic activity

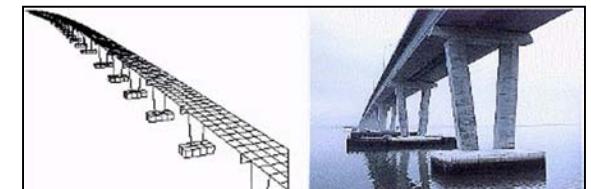
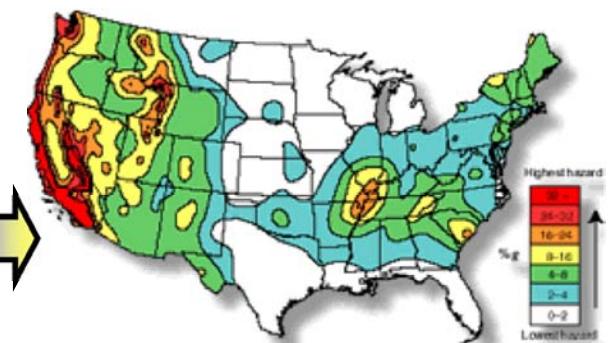
Surface Deformation Measurement



Earthquake Hazard Information (Stress Map)



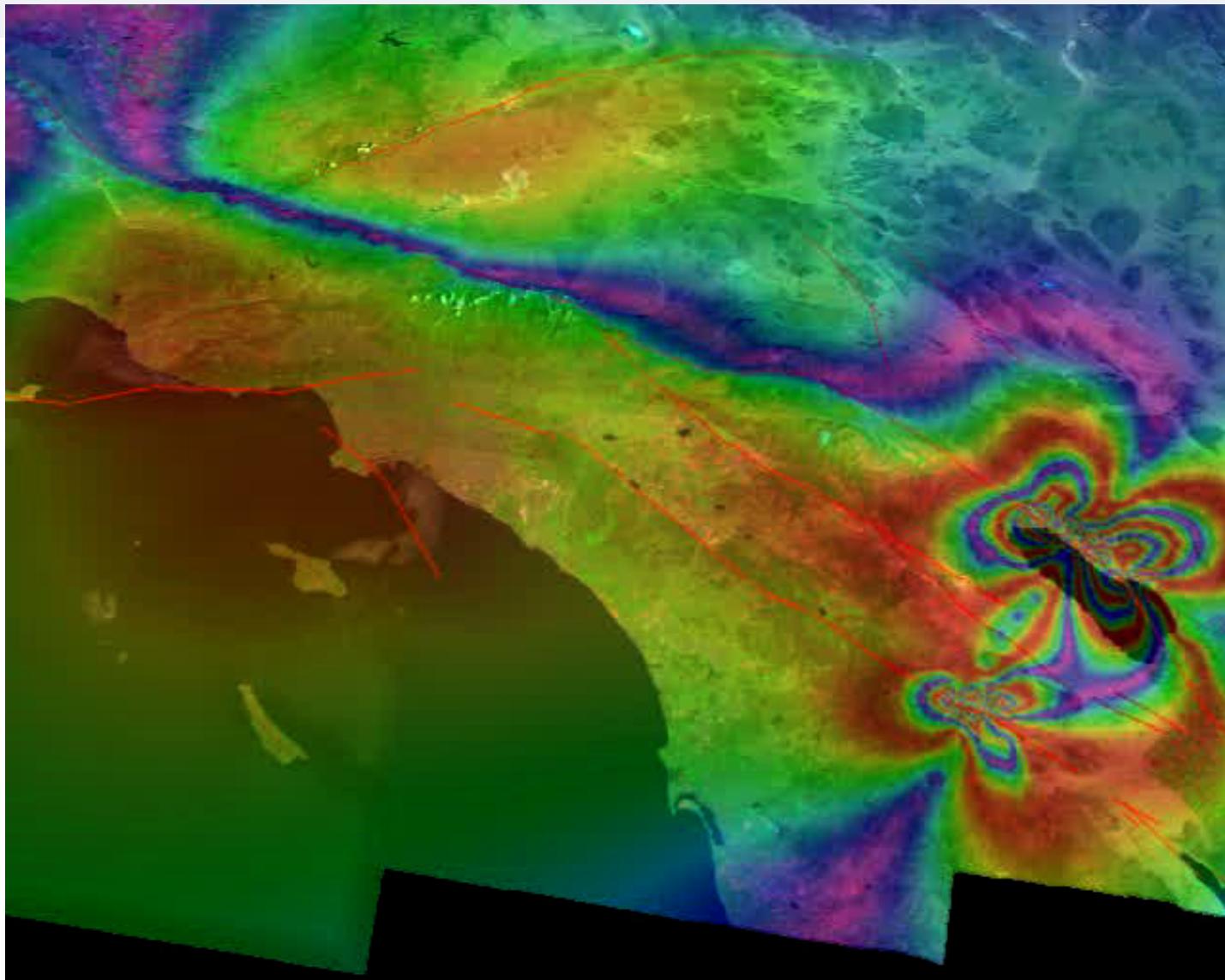
Improved Planning and Preparation





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InSAR Data Promise to Revolutionize Earthquake Understanding





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A Decadal Plan – Finally!

- NRC Earth Science and Applications Decadal Survey Pre-publication released on January 15
 - **The Decadal plan recommends a path forward that restores US Leadership in Earth Science and Applications and averts the potential collapse of the system of environmental satellites.**
 - 1) Focuses on climate measurements related to climate forcing, ice sheet and sea level changes, shifts in cycling of water, and extreme weather and heat events
 - 2) Restores and expands the capability to observe natural hazards and ecosystem changes
 - 3) Makes key new measurements, such as tropospheric winds and all-weather temperature and humidity soundings, to improve the existing weather forecasting system.



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NRC Report Highlights

- Key recommendations
 - NASA should implement a set of 15 “strategic” missions—phased in over the 2010-2020 period—ranging in cost from less than \$300 million up to \$900 million.
 - NASA should create a “Venture” class of missions (ranging from \$100 - \$200 million) that fosters innovative ideas and higher-risk technologies
 - NOAA should transition three current research observations to operations.



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Societal Issues

□ By the Year 2050 ...

- There may be 9 billion people and
 - > 6 billion tonnes per year of greenhouse gases
 - > 60 million tonnes per year of urban pollutants
- Given these possible scenarios we will tax the world's resources
 - Withdrawing 30% of the available fresh water
 - Converting 65% of frontier forests
- We will live increasingly in health and hazard risk areas
 - 80% will live in urban areas
 - > 25% will live near earthquake faults
 - ~ 2% will live on coastlines within 1 meter of mean sea level



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Mission Opportunities

| Missions | Instrument | Description | Launch |
|---|---|---|----------------------------|
| SMAP DESDynl XOVWM | L Radar Ku Scatterometer | Global Soil Moisture Seismology, Biomass, Ice Dynamics Ocean surface wind vector | 2013 |
| GPSRO | GPS | Temperature, water, electron density | 2013 |
| HyspIRI Clarreo | Hyperspectral | Land surface, Vegetation Solar radiation | 2015 2012 |
| ASCENDS | 2 um Lidar | Day/night height integrated CO₂ | 2016 |
| SWOT | Ku/Ka Radar | Sea surface & terrestrial water | 2016 |
| ACE | MSPI/W Radar | Aerosols, clouds, biogeochem | 2016 |
| PATH | GeoSTAR | Global water and temperature | 2020 |
| GRACE II | RF/Laser ranging | Gravity Fields for water movement | 2020 |
| SCLP | Ku Radar | Cold land processes | 2020 |
| GACM | SMLS | Ozone, air quality | 2020 |



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Technology Needs

| Missions | Instrument | Areas |
|--------------------------|-----------------------------|--|
| SMAP DESDynI XOVWM | L Radar Ku Scatterometer | power amp, Power storage, ADC/FPGA, Mesh antenna, Compact T/R, R/F & I/F, Feed, FPGA |
| GPSRO | GPS | Blackjack, OSSE |
| HyspIRI Clarreo | Hyperspectral | UV/VIS/NIR, TIR testbed, Antenna, data compression |
| ASCENDS | 2 um Lidar | 5W laser, OSSE |
| SWOT | Ku/Ka Radar | Power amp, Low power T/R, FPGA |
| ACE | MSPI/W Radar | FPA, EIK, airborne demo |
| PATH | GeoSTAR | MMIC, Correlators, OSSE |
| GRACE II | RF/Laser ranging | Drag-free, formation flying |
| SCLP | Ku Radar | EIK |
| GACM | SMLS | SIS mixer, testbed, OSSE |



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- Dr. Jason Hyon, Chief Technologist, jason.hyon@jpl.nasa.gov

■ Missions and instruments:

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- Dr. Steven Bard, Manager, JPL Earth Explorer Missions Office, steven.bard@jpl.nasa.gov



Above all else, the people of JPL are explorers.

We hope you can join us

